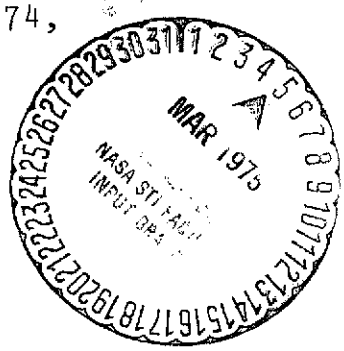
(NASA-TT-F-16020) ESSAYS ON THE PSYCHOLOGY OF OPERATOR LABOR (Scientific Translation Service) 375 p HC $10.00 CSCL 05J

N75-17947 THRU N75-17958 Unclas G3/53 10235

ESSAYS ON THE PSYCHOLOGY OF OPERATOR LABOR

Ye. A. Mileryan, Editor

Translation of: "Ocherki psykhologii truda operatora," Moscow, "Nauka" Press, 1974, 308 pp.



ORIGINAL PAGE IS
OF POOR QUALITY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 JANUARY 1975

TABLE OF CONTENTS

	Page
Annotation	1
Ye. A. Mileryan. Emotional-Volitional Components of Operator Reliability	3
Ye. A. Mileryan. Discussion and Theoretical Summarization of the Experimental Data	100
A. V. Solodkova. On the Effect of Emotional States on Operator Thinking	143
P. B. Zil'berman. The Operator's Emotional Stability	167
V. S. Genes, Yu. M. Madiyevskiy. Increasing the Reliability of Labor of Railroad Engineers	209
Ye. P. Il'in. "Operational Calm" and the Optimum Regulation of Human Working Capacity	226
O. P. Shvetsov. Attention and Its Role in the Operator's Work.	252
V. V. Mistyuk. Verbalization and Imagery in the Process of Formation of Operator Labor Skills	281
V. M. Bondarovskaya. Certain Aspects of the Psychological Analysis of Programmer Activity	303
L. I. Tomashevskaya. The Reaction of the Cardio-Vascular and Sympathico-Adrenal Systems to Intellectual Activity with Emotional Stress	335
Ye. A. Mileryan. The Psychological Certificate of the Computer.	352

PRECEDING PAGE BLANK NOT FILMED

ANNOTATION

Present-day scientific and technical progress in all spheres /3* of industrial production, construction, transportation, power engineering, agriculture and military technology has brought to the fore the problem of increasing the effectiveness and reliability of the work of operator-specialists who maintain, program, control, service and monitor complex automated systems.

A necessary condition for the successful solution of this problem is the implementation of the planned study of the psychological features of man's labor under the conditions of technical progress.

This collection presents studies that have been done in recent years at the Ukrainian Institute of Psychology, Leningrad State University and Kharkov Pedagogical Institute, on the initiative and with the unfailing support of Academician Aksel Ivanovich Berg and his colleagues.

This book presents the results of many years of theoretical and experimental research on the operator's work activity under various working conditions, and an attempt is made to formulate a new engineering-psychological conception of the ways of matching the characteristics of technical devices with the operator's

*Numbers in the margin indicate pagination of original foreign text.

N75 17948

EMOTIONAL-VOLITIONAL COMPONENTS OF OPERATOR RELIABILITY

Ye. A. Mileryan*

The rapid technical progress in all spheres of industrial production, construction, transportation, power engineering, agriculture, and military technology has brought to the fore the vocation of the operator-specialist, who controls, services, and monitors the most diverse automated systems. /5

The present stage of development of our society is marked by the integrated mechanization of production processes and by the transition from the automation of individual units to the creation of completely automated shops and production facilities. The accelerated development of integrated mechanization, automation, and conversion to chemical processes of industry and agriculture, and the extensive application of electronics, calculating machines, and cybernetic devices, as well as other very recent achievements of science and technology, are causing fundamental changes in the nature of labor. Participation in present-day production increasingly requires a broad polytechnical education on the part of the members of our society.

The further development of technology and the introduction of new and progressive forms of work organization naturally bring about the extensive combination of vocations and work functions, the

*Kiev, USSR Institute of Psychology.

PRECEDING PAGE BLANK NOT FILMED

broadening of the worker's range of vocational skills and the raising of the level of his qualifications.

The progressive development of industry and agriculture is inseparably connected with the appearance of new operator vocations with a wide range of skills. Mastering these most promising vocations requires the ability to plan, program, control, monitor, regulate, and service various automatically functioning machines, machine tools, and units; the ability to determine the causes of trouble promptly and quickly, guided by the signals of monitoring and measurement instruments; and the ability to correct equipment troubles and to restore the operation of automatically functioning systems in all cases in which it is disrupted. /6

In order to perform all these functions successfully, the operator must not only master a wide range of polytechnical knowledge relating to mechanics, electronics, hydraulics, and production technology, but also know how to use all this knowledge under various production conditions.

"In the age of automation," writes Academician A. I. Berg, "man has proved to be one of the links in a new chain: The machine — the automatic device that controls it — man. This chain becomes complicated when many machines, production lines, shops, and plants are operated automatically. Trouble-free operation of mechanisms and machines does not exist. This is equally true of the elements of manual control and even more true of the elements of automatic control. Even a temporary failure to function on the part of any link (and in a chain of this kind there are no important and unimportant links) requires immediate intervention and the execution of a number of control operations, often in a period of time that is so short that it exceeds man's physical and psychophysiological potentialities." [1].

Performing the operator's functions in present-day systems places an extraordinarily great responsibility on the worker since the quality of the work of the system that he controls and the

preservation of the equipment, products of the work, means of transport and people's lives depend to a great extent on the correctness, promptness, freedom from error and effectiveness of his actions.

Experience in the control of the present-day equipment up to now clearly indicates that errors made in analyzing the causes of breakdowns in power, transportation, industrial, and other systems often bring about inadequate actions by operators that lead to emergencies and sometimes to catastrophic consequences.

The urgency of this problem is confirmed by the statistics relating to motor-vehicle mishaps and accidents. Thus, according to U. N. data, automobile accidents annually take the lives of about 250,000 people and cause wounds and disabling injuries to more than 7,000,000. Investigation of the causes of automobile mishaps and accidents has shown that 72 — 80% of them occur through the fault of a person involved. Thus, man is the least reliable link in the system "man — automobile — road."

Special studies of trained drivers have shown that driving an /7
automobile on an icy road under conditions of poor visibility, fog, and rain, especially at night, when there is the blinding effect of the headlights of oncoming cars, requires of the driver increased work capacity, emotional stability, discipline, calmness, and the ability, without becoming flustered, to evaluate adequately and quickly the road situation, to make the correct decisions quickly and to implement them promptly in motor actions.

As experiments have shown, far from every experienced driver has all these qualities. Thus, the need has been demonstrated for psychological selection and systematic re-examination before runs of the drivers of passenger buses, inter-city buses, and taxis, as well as other vehicles that make runs regardless of the weather.

A study of 10,000 automobile accidents done by psychologists has shown that the smallest number of accidents are caused by drivers who have families and a normal lifestyle. In comparison to them, 1.7 times more accidents are caused by students, secondary school pupils and young drivers. The worst offenders with respect to tragic automobile accidents are people who have an immoral lifestyle, old bachelors, divorcees, alcoholics, neurasthenics, etc. As a result of this research, the following extraordinarily important conclusion was drawn: "A person drives a car the same way that he lives."

Thus, it was established that there is a direct relationship between the moral and social makeup of an individual and the effectiveness of his work activity.

Further studies of this psychological regularity have proved the complete correctness of this assertion with respect to any vocation.

Conscientiousness, honesty, discipline, organization, high morality, industriousness, and interest in one's work are the qualities that primarily determine the vocational fitness of each specialist and the reliability and effectiveness of his work.

Thus, the reliability of an operator's work is determined by his moral, emotional, and volitional qualities. In this connection, there is a need for comprehensive psychological study of operators' activity with the aim of finding ways to increase the effectiveness and reliability of their work. The problem of the reliability of an operator's work in a complex control system is one of the central /8 problems of engineering psychology. Intensive work on individual questions involved in this problem is now being done by both foreign and Soviet scientists (A. I. Berg, K. M. Gurevich, D. F. Gorbov, B. F. Lomov, V. D. Nebylitsin, V. P. Zinchenko, A. N. Leontyev, G. M. Zarakovskiy, M. I. Bobneva, A. Chapanis, MacCormick, etc.). The efforts of these researchers are aimed at resolving both theoretical and practical questions involved in this problem.

Thanks to the research of the aforementioned authors, definite progress has been made in recent years in formulating and working out approaches to the study of the key questions of the theory of the reliability of an operator's work in a complex systems-technology complex. Experimental study of this problem (P. L. Aldzher, K. M. Gurevich, B. F. Lomov, Ye. A. Mileryan, A. Chapanis, etc.) has opened the way to a further increase in imperviousness to hindrances, accuracy, speed, and other indicators of the reliability of man's work in the system of "man — machine." At the same time, as B. F. Lomov justly observes, the resolution of this problem is still in its initial stages [2].

In elucidating the role of emotional-volitional components in the work of a pilot, Ye. A. Derevyanko has established that the reliability and productivity of this work are determined, on the one hand, by the maximum potentialities of the organism, and on the other hand by the level of emotional-volitional tension, which regulates the degree of utilization of these maximum potentialities. [3] Thus, this author's research clearly shows the extraordinarily important role of the emotional-volitional sphere of the operator's personality as a factor in the willful regulation by the individual of his strength, energy resources, and work capacity according to the specific working conditions.

An important contribution to the work on urgent questions of reliability has been made by the American psychologist A. Chapanis, who, thanks to long and comprehensive study of individual aspects of this problem, has developed a mathematical method for assessing the degree (extent) of the influence of errors made by an operator on /9 the magnitude of the disturbance caused in the operation of the system that he controls.

In order to increase the reliability of the operator's work, A. Chapanis has proposed that his activity be based on the principle of duplication, according to which the work is done independently by two operators. A special monitoring device compares the results of their work and allows only identical responses to pass through.

Implementation of this principle makes it possible to reduce the number of errors usually made by an operator from 1 — 2 per hundred to 31 per million actions.

Another of the methods proposed by this researcher to increase the reliability and accuracy of the work of the system "man and automatic device" is implemented by including in this system supplementary intermediate circuits that provide the operator with information about the results of his controlling actions well before they affect the system's output.

Further improvement of the method proposed by A. Chapanis has enabled B. F. Lomov and his colleagues to establish by means of specially organized experimental studies that the indicators of the accuracy of operator actions vary depending on the properties of the signal. "The closer the properties of the signal are to threshold values," this author writes, "the more errors a person makes in his responses to the signals. The magnitude and frequency of the errors grow as the complexity of the task and the operator's work rate increase."[4]. There is an individual work rate that insures maximum accuracy. Making the work rate too low or too high leads to an increase in the number of erroneous actions.

In summing up the results of the studies that have been done under his direction, B. F. Lomov comes to the conclusion that there is a whole series of paths leading to an increase in the reliability and accuracy of the operator's work. The principal paths are the following: Selection and training of operators; rational organization of working conditions; consideration for the features of the machines' design and matching them with human potentialities; designing the machines, the working environment, and work operations in accordance with human potentialities. Practical implementation of these conclusions has made possible a radical redesigning of control panels by replacing arrow-indicator instruments with an integral picture of the situation existing at a given moment. A considerable improvement in the work of operators has been achieved as a result of the application of the "pictorial principle," and this in turn

has led to a decrease in fatigue and to an increase in the effectiveness and reliability of the performance of the functions assigned to them.

We encounter an original interpretation of theoretical questions /10 of reliability in the works of M. I. Bobneva, who has proposed that in studying this problem we proceed from the stochastic nature of human behavior, taking into account the possibility of both regular and random failures in an operator's work. This author considers regular failures those operator errors whose causes can be discovered through research and can be eliminated by creating optimum working conditions, by changing the character of the activity, by improving the technical devices, by psychological selection of operators and by other means. Random failures are seen as those errors that are brought about by causes that are unknown to us and that are connected with the stochastic nature of human behavior.

Without denying the legitimacy of the stochastic approach to the problem of reliability, we must still express our doubts concerning the possibility of assuming, as M. I. Bobneva does, that an operator's random errors cannot be studied and explained by any known cause. It is obvious that the primary task of research on random operator failures is precisely to ascertain the causes of such failures. This is necessary in order to find ways of neutralizing these factors, thereby increasing the reliability of man's work.

The doubts expressed above can be resolved by setting up special experimental research projects aimed at studying random failures in human activity.

Through experimental study of operator lapses and failures, R. S. Lincoln has established the existence of so-called passive errors caused by disruption of the functions of thinking, memory, and attention. A group of active errors was also distinguished. They are manifested in distorted interpretation of events, erroneous identification of signals, performance of inadequate actions, etc.

In order to eliminate the errors of this group, R. S. Lincoln has proposed that a new principle be used in constructing control panels. The essence of this principle consists in matching indicators with control elements, as well as in putting together signal instruments in ways that are more convenient for remembering and for switching attention [5].

In the works of V. D. Nebylitsin, K. M. Gurevich, V. F. Matveyev and O. K. Kononkin the problem of the reliability of the operator's work is viewed in the light of the science of the types of higher nervous activity. In a special work devoted to the problem of reliability, [6] V. D. Nebylitsin has advanced a hypothesis concerning the existence of a connection between certain characteristics of an operator's working qualities and basic traits of his nervous system. These traits are inborn and unchanging; therefore, they constitute constant parameters of reliability. Among an oeprator's working qualities, this author distinguishes the following: long-term endurance, which is based on the strength of the nervous system; endurance in the face of extraordinary stress and overstress, which must be connected either with the strength of the nervous system with respect to stimulation or with the equilibrium of nervous processes; imperviousness to hindrances related to the action of the environmental factor (temperature, pressure, humidity, noise, acceleration, hypoxia, etc.), which also must be directly conencted with the strength of the basic nervous processes; and rea reaction to unforseen stimuli — a function of the equilibrium of the processes of stimulation and inhibition. As this author assumes, switching ability is connected with the mobility of nervous processes. At the same time, he emphasizes that the trait of mobility of nervous processes does not have an unequivocal definition and is in need of detailed research. /11

Questions of the reliability of the operative personnel of power systems have been studied over a long period of time by an entire group of Moscow psychologists under the direction of K. M. Gurevich: These studies have shown that erroneous actions or inaction by operators in complex and responsible situations are definitley connected with individual difference in the strength

and balance of the basic nervous processes of the brain. This confirms to a certain extent the theoretical propositions advanced by V. D. Nebylitsin.

A substantial contribution to resolving questions of reliability has been made by the experimental studies of the emotional stability of the operator that have been done by V. L. Marishchuk, who used an original method in doing a study of the emotional stability of cadets at air academies and pointed out certain possibilities for improving it through physical training. /12

T. T. Dzhamgarov has developed and approved, together with his colleagues, a new method for the psychological testing of emotional stability in selecting cadets for Air Force academies.

A. I. Gubinskiy and A. M. Polovko have proposed a method for the quantitiative assessment of the reliability and effectiveness of operator activity that is based on a hypothesis concerning the possibility of a direct application of the theory of the reliability of technical systems to the assessment of the reliability of an operator's work.

Assuming that an operator's activity in controlling any technical system consists of a hierarchical series of levels, each of which has a definite structure, the authors proposed that the reliability of the operator's work in terms of the absence of failures and the speed with which he performs each of the structural functions be assessed in accordance with this. The value of the probability of the reliable performance by the operator of the functions assigned to him and of individual operations may be computed by using both experimental data and data available in the literature.

Without denying in principle the possibility of a purely engineering approach to assessing the reliability of the human element in a control system, we must point out at the same time that it is inadequate and must emphasize that it is necessary to work out psychological criteria and methods for studying the work activity

of the operator, who is a working entity not only endowed with vocational knowledge, abilities, and skills, but also having certain moral, emotional, volitional, and other personal qualities; the effectiveness and reliability of his work activity depends first of all on the perfection of these qualities.

We encounter the logical-probability approach to studying certain theoretical questions of reliability in the works of G. M. Zarakovsky, who has developed an algorithmic approach to the psychophysiological analysis of the work process. The results of using this methodological technique to study reliability have proved to be positive.

What has been said indicates that thanks to the research done /13
both in our country and abroad, a certain amount of progress has now been achieved up to the present time in clarifying the most important, crucial theoretical questions involved in the problem of reliability. Experimental study of this problem has yielded the first practical results.

At the same time, we must say that the ultimate solution of this problem is still far off. Extraordinarily great methodological difficulties are involved in reaching this solution.

In this connection, we consider promising the systems-structural approach to studying the problem of reliability. This approach involved first of all ascertaining the specific features of the structure of operator activity and determining the characteristic difficulties, errors, and failures that a person encounters when mastering both the individual elements and the entire structure of this activity. A mandatory condition of such study is the formation of vocationally important knowledge, abilities, and skills, and the inculcation of the personal qualities that are needed in order to master this vocation. By taking this path, we will be able not only to ascertain the presence of the various attributes that characterize the productivity of an operator's work, but also to establish the psychological conditions and causal relations that raise or lower the reliability and effectiveness of his work.

Implementation of the systems-structural apprach to the study of operator activity is inseparably connected with finding out the general structure of this activity for the purpose of ascertaining the objective and subjective conditions that determine the reliability and effectiveness with which a person performs the structural functions assigned to him.

In structural analysis of the operator's work one should proceed from A. N. Leontyev's conception, which reveals the general psychological structure of man's work activity. According to this conception, any work activity is always characterized by an orientation toward the achievement of a definite work goal. According to K. Marx's definition, a conscious goal acts as a law in determining the method and nature of man's work activity. At the same time, psychological analysis of the work process makes it possible to distinguish "separate activities," or links, that insure the achievement of partial, intermediate work goals. "We use this term," A. N. Leontyev and D. Yu. Panov point out, "to denote a complex totality of processes that are united by a single general orientation toward the achievement of definite results." [7].

Orientation toward final and intermediate work goals makes it /14
possible to establish the content and conditions of performing the corresponding partial activities, each of which is a mandatory component of the general structure of a given work activity. The content of a separate component of the work structure is a definite totality of mental and practical actions characterized by their orientation toward the achievement of intermediate work goals.

Research on vocational structures should not only bring to light their structural components, but also reveal the functional connections that exist among them. All this is necessary in order that we may move on from the isolated study of work functions that is widespread at the present time to the integral-structural research on the reliability and effectiveness of the performance of these functions as a part of one or another work activity.

Thus, in studying general-work structures, one should first of all clearly distinguish the overall and intermediate goals whose achievement will insure that the work is performed successfully. Orientation toward the goals of work activity will make it possible to single out the basic components of its structure and to determine the makeup and interconnection of work actions, as well as to examine the various methods for performing them. In the course of such study, it is possible to ascertain the demands made on man's psychic functions, which insure the successful performance of both the separate elements and the entire integral structure of the work activity.

1. Structural and Functional Features of Operator Activity

Psychological study of the operator's work should reveal its functional structure. This is necessary in order to resolve scientifically the question of the optimum distribution of functions between man and machine, as well as to work out effective methods for work training and vocational training.

Work in present-day highly mechanized and automated production involves controlling and monitoring the operation of automated systems of machine tools, machines, and units. The vocation of the operator, who performs the functions of tracking, monitoring, and controlling production processes, is beginning to play the major role in this kind of production.

Summarizing the results of the psychological study of the activity of operators who work in various branches of production and transportation and in military organizations has made it possible for us to divide the representatives of this vocation in these fields into the following basic groups: 1) The operator-technologist, who performs the functions of tracking, monitoring, and regulating the course of various technological processes with the aim of keeping them within the limits given by the program; 2) the operator-dispatcher, whose job is to receive and process information, as well as to solve problems connected with organizing the movement of air, rail, and water transport; 3) the operator who /15

operates moving units by means of remote control (control by means of radio of the movement of aircraft, torpedoes, rockets, guided missiles, etc.); 4) the operator who is in a moving unit and controls it directly (pilots, steam and diesel locomotive engineers, ship pilots, and drivers of streetcars, trolleybuses, motor vehicles, and other kinds of transport.)

Psychological study of these operator vocations has shown that each of them makes its specific demands on a person. At the same time, the vocational activity of operators who control the most diverse systems, of servicemen, and of workers who operate machine tools is very similar with respect to its psychological structure. This makes it possible to determine the general structure of activity for these vocations, which is connected with the performance of the most diverse production operations.

The works devoted to the psychological study of the operator's work have clearly shown that an initial and mandatory component of the structure of the activity of the representatives of this vocation is the function of tracking the course of events and the state of the systems that they control.

The operator usually receives information in coded form. In the general flow of information received, the operator must carry out a purposeful selection and decoding of the useful signals, so that by summarizing the important attributes of the existing situation he can recognize and have a clear mental picture of the current state of the system that he is controlling.

In their analyses of operator activity, V. P. Zinchenko, N. I. Maizel, A. I. Nazarov, and A. A. Tsvetkov also point out that during the first stage of his processing of the incoming information, the operator decodes the information received, which involves "...a mental reconstruction of the real attributes of the states of the entity, knowledge of which is necessary in order to accomplish the tasks confronting the operator." [8]. Selectively receiving, decoding, and processing the information, the operator must not

only picture the existing situation, but also trace the trend of the /16
further course of events by means of extrapolation in order to foresee the possible consequences of their development.

Thus, a necessary initial condition for the successful performance by the operator of his functions is active selective perception and tracking of the signals that reflect the dynamics of the parameters characterizing at a given moment the state of the systems being controlled. In the process of tracking, the operator selects useful information, analyzes the existing situation and determines the main trends and possible consequences of the further development of events. "Constantly monitoring the dynamics of the parameters, following unfolding and developing events and extrapolation insure the necessary readiness for action on the part of the operator," D. A. Oshanin writes in this regard. [9].

What has been said enables us to assert that the functions of active and purposeful tracking, in the process of which the operator perceives, selects, analyzes and decodes current information and develops an adequate picture of the state of the processes that he is controlling and of the trends of their further development, are an important and mandatory initial element of the structure of the activity of every operator.

In this connection, it should be noted that there is a considerable number of works in foreign psychological literature that are devoted to the experimental study of the process of tracking. However, these works, as B. F. Lomov and S. N. Leviyeva correctly note, "...do not deal with questions of the structure and mechanisms of the activity of tracking itself." [10].

It is obvious that the leading role in the structure of this kind of activity belongs to the worker's ability attentively to perceive, analyze, decode and summarize current information, so that he can promptly grasp the state of the system that he controls and the trends of the further development of events.

The next element of operational-monitoring activity involves organizing the information that the person has obtained in the process of tracking into an integral system of interconnected characteristics, which leads to the synthesis of an integral and clearly differentiated image or model of the situation, to a grasp of the existing situation and to the clarification and formulation of the conditions of the task confronting him.

The next state of operator acitvity is usually connected with the appearance of a plan for solving the problem. After comprehending, analyzing, and clarifying the conditions of the task confronting him, the worker strives to formulate a definite approach to solving the problem and, in implementing his plan, to find the optimum program for utilizing the means and methods of solving it that he has at his disposal. As the studies of D. N. Zavalishina [11] and V. N. Pushkin [12] have shown, in the process of solving problems a person can make use of a ready-made program, i. e., a definite algorithm of actions that is already known to him. However, under atypical conditions his intellectual activity becomes creative. In this case we have a nonstereotyped application of knowledge, which involves the transformation of unified spatial images and concepts. The leading role in the operator's activity is played by practical operative thinking, the specific features of which have been studied in detail by B. M. Teplov, [13] V. V. Chebysheva, [14] B. F. Lomov, [15] N. G. Levandovskiy, [16] V. Ya. Dymerskiy, [17] D. N. Zavalishina, [18] V. N. Pushkin [19] and other authors. The studies done by these authors have shown that in this kind of intellectual activity, figurative and verbal-logical thinking are inseparably connected. This insures a unified and at the same time specific reflection of the problem situation and also brings about a selection of adequate methods and ways of accomplishing the task that has been posed.

The next element of the structure that we are examining involves the operator's working out a strategy for his behavior, as well as concrete planning of influences of the system that he controls. This planning is manifested in a mental picture of the temporal and

spatial sequence of all the actions, techniques, and operations that /18
insure the achievement of the goal that has been posed. Operative thinking is used at this stage to work out a strategy and an operative plan of action, whose implementation is aimed at accomplishing the task that has been posed.

An important element of the structure of operator activity is the practical action directly connected with regulating and controlling the course of the performance of production operations. Despite the different nature of these actions in the case of operators, servicemen, machine tool workers, and other specialists, they all constitute a motor implementation of a program of regulation and control that has been worked out previously.

The moment of taking action, when the implementation of this program begins, is determined by the effect of previously expected signals. It is natural that in this element of operational-monitoring activity the leading role belongs to the sensomotor abilities and skills that are normally used to control the given systems. Here speed, accuracy, coordination of movements, and matching the actions performed with the program previously worked out come to the fore.

The final stage of the operator's activity is the monitoring of the planned operations. This assessment is usually accomplished by comparing the new state of the system being controlled that has been brought about through the operator's influence with the projected goal. Here the operator takes into account the changes that have been made in the surrounding situation through the influence of the various factors connected with the given system. The principal task at this stage is to discover and correct disparities between the results and the goal of the activity.

With respect to its content and work techniques, the final stage resembles to a great extent the initial elements of the structure being described.

Here too the operator performs tracking, analyzes and summarizes information, develops an adequate picture of the state of the system being controlled, etc. However, all of these actions are subordinated to the goal of monitoring and assessing the results of the performance of the tasks confronting the operator. It is natural to assume that under certain conditions the final element /19 may become the first element in a structure of activity that may now be directed toward the accomplishment of new tasks.

The structure of operator activity described above should be viewed as an approximate scheme, since under actual working conditions the individual elements of this structure may be connected and related in different ways. At the same time, all of them are mandatory structural components of this kind of work.

2. Psychological Study of the Effectiveness of Certain Methodological Techniques of Training Operators

A purpose of the next cycle of our research was the study of the psychological features of the formation of the abilities and skills of operators that are of general importance and are necessary for work involving a remote-control panel. By ascertaining the general structure of operator activity, we have been able to work out a new method for the psychological study of the features of the formation of its component functions, a method that models this structure. For this purpose, we constructed a special experimental unit consisting of a panel for the test subject (see Figure 1 on page 20) and a panel for the experimenter (see Figure 2 on page 20).

The panel of the test subject has a vertical information panel and a slanting control panel. On the right side of the vertical panel there is a semi-transparent screen that conveys information in the form of a white dot that moves along a curved trajectory. Six curved lines, each of which represents a possible trajectory of this dot, are pictured next to the screen. Under each of the curved lines there is a tumbler switch, which is used for objectively recording the time spent by the test subject on

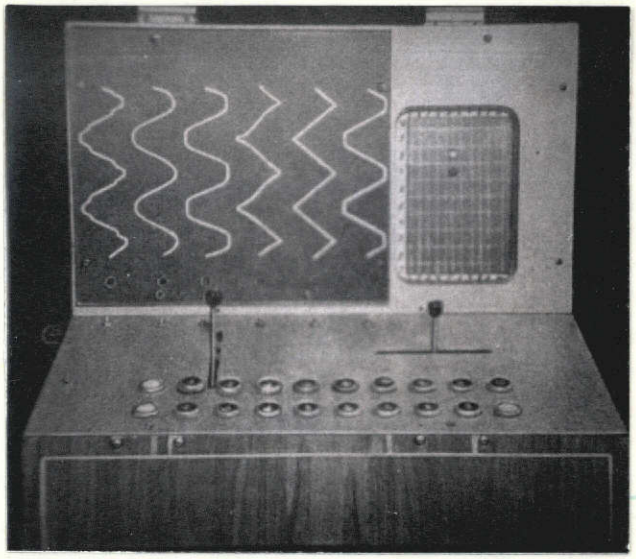


Figure 1. Unit for studying operator activity. Test subject's panel.

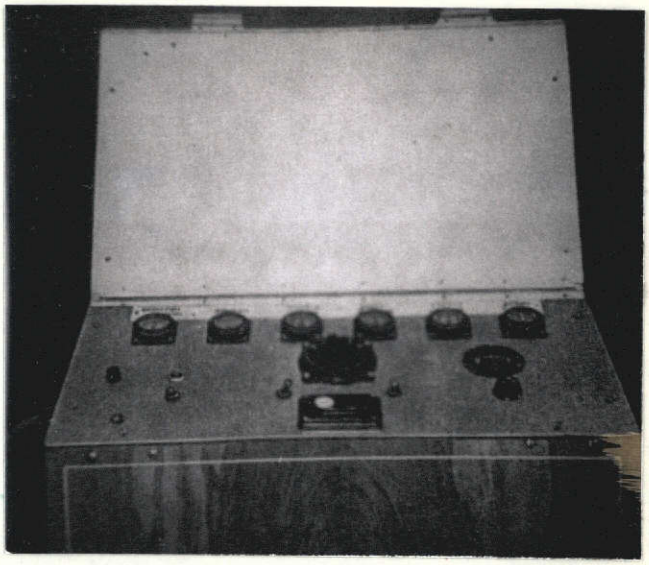


Figure 2. Unit for studying operator activity. Experimenter's panel.

recognizing the form of the white dot's trajectory across the screen. On the information screen the test subject also sees a red dot, whose movement he can determine through remote control by moving the levers mounted on the slanted panel. By using the right lever, the test subject can make the red dot move to the right or left, and by moving the left lever he moves it up and down. When the two levers are operated simultaneously, the red dot can move in any direction on the screen. The panel of the test subject has two rows of buttons, with 10 buttons in each row. The buttons are marked by the numbers 1 to 10. The upper row is labeled "vertical" and the lower row "horizontal." The semi-transparent screen has a coordinate grid. Using this grid the test subject can determine /20 the coordinates of the moving dot and, by simultaneously pressing the proper buttons, can record his answer. For example, if the horizontal position of the dot is marked by three divisions and the vertical position by five divisions of the coordinate grid, then in order to record the coordinates the test subject should simultaneously press the third button of the upper row and the fifth button of the lower row. The apparatus records the number of correct and erroneous actions by the test subject in determining the coordinates of the moving dot.

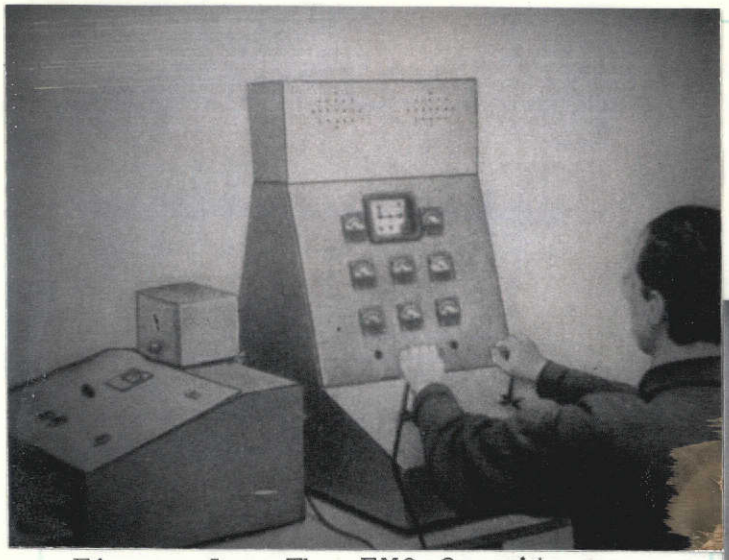
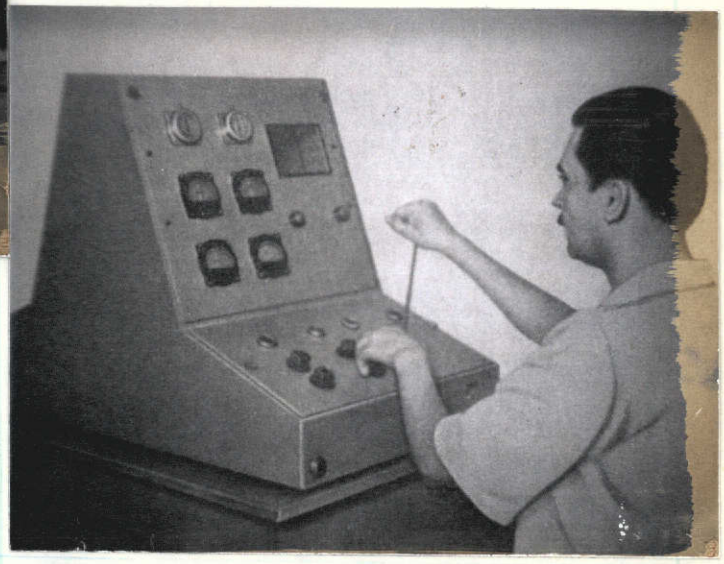


Figure 1. The EMO-3 unit for studying the operator's thinking.



The attentiometer. Test subject's panel.

TABLE 1

SUMMARY TABLE OF THE DATA OBTAINED FORM THE FIRST SERIES OF EXPERIMENTS

No.	Test subject	Number of repetitions required to develop the skills and abilities for			Total number of repetitions of the program
		Executing control	Giving the coordinates	Identifying the images	
1	S.A.	8	4	19	23
2	N.V.	16	2	20	23
3	K.R.	21	5	24	30
4	G.B.	27	3	26	33
5	G.P.	25	5	30	36
6	B.A.	38	4	31	38
7	V.V.	35	19	27	44
8	P.N.	24	4	31	44
9	R.V.	41	15	40	49
10	M.R.	59	37	43	59
11	S.G.	49	37	43	49
12	M.V.	60	27	56	60
13	G.Ye.	61	49	39	61
14	B.F.	53	25	51	63
15	B.B.	49	33	27	63
16	B.N.	59	31	49	64
17	S.S.	66	51	35	66
18	V.V.	35	17	24	69
19	E.N.	71	47	39	71
20	S.D.	58	41	31	72
Arithmetic Mean		42,75	22,08	34,93	51,50

On the experimenter's panel there are six counters, a tumbler switch with an indicator, a regulator with an arrow indicator of the speed with which the trajectory is revealed, a program switch, buttons for starting and stopping the program, a light switch, and other devices.

The impulse counters on the experimenter's panel record the following indicators of the work of the test subject:

1) the length of the program;

2) the tracking time, during which the test subject matches the movement of the red dot controlled by him with the trajectory of the program dot, i. e., the white dot;

3) the total number of readings of the coordinates given by the test subject in the course of the experiment;

4) the number of correct readings of the coordinates;

5) the time required by the test subject to identify correctly the form of the trajectory of the white dot across the screen;

6) the total number of programs presented to the test subject.

The unit described was the technical means for a new method that puts into practice principles of training, of modelling the general structure of activity, of objectivity in recording the results, and of optimality of the test conditions.

Use of this method has opened up new prospects for the study of the regularities of the formation of all the basic components of the structure of operator activity and for the study of the reliability of their functioning.

For the purposes of this research we did two series of studies, in which 40 test subjects took part. In both the first and second

series of experiments, the test subjects were individually trained to work at the control panel.

Twenty test subjects were trained in the first series of experiments. After they had mastered the instructions and become familiar with the work techniques, they were asked to follow continuously the movement of the white dot across the screen and, by moving the control levers, to move their dot, i. e., the red dot, /21 in such a way that it would be matched with the white dot at all times. At the same time, the test subject had to determine the form of the trajectory of the white dot. In solving this problem, he could be guided by the model trajectories located next to the screen. The moment when the test subject identified the dot's trajectory was objectively recorded by pulling the tumbler switch located under the appropriate standard trajectory. Along with performing these functions, the test subject had to monitor his own activity.

The test program was drawn up in such a way that the movement of the white dot across the screen was periodically (every 10 seconds) interrupted by three second pauses. During this time the white dot was extinguished and ceased its movement, and the test subject had to determine the coordinates of the dot's last location and give them by pressing the proper control buttons. When the pause ended, the dot was again lit and resumed its movement, starting from the point where it had stopped when the pause began.

In both the first and second series of experiments, the test subjects were given individual training until they acquired the ability to follow and track the dot within 50% of the entire duration of the program, to determine the form of the trajectory of the white dot within 25% of the time allotted to the program and to give at least 75% of the coordinates without error.

The training ended when these indicators were reached. The number of repetitions of the program necessary for this served as an objective criterion of the effectiveness of the training method chosen.

At the beginning of the experiment each of the test subjects was familiarized with the apparatus, the techniques of working with it were explained to him and he was given instructions that stated the purpose of the training. In order to eliminate the effect of fatigue, the duration of each session of the experiment did not exceed 30 minutes. /22

It is most convenient to begin the analysis of the experimental data obtained in this study by examining the general indicators characterizing the success of the test subjects who took part in the first series of the experiments in mastering the various components of the structure of operator activity. In Table 1 the test subjects are ranked according to the total number of repetitions of the program* that were required for them to master the work at the control panel. As may be seen from the data presented in the table, the formation of abilities and skills involved in working at the control panel required from 23 to 72 repetitions of the program and an average for the group of 51.5 repetitions, which indicates the existence of significant individual differences in the capacity of our test subjects for mastering this kind of activity. These individual differences come out even more clearly when we compare the number of repetitions required for the test subjects to master the individual components of this structure. Thus, from 8 to 71 repetitions were required to master the control skills. From 19 to 56 repetitions were required in order to learn how to identify correctly the forms of the trajectories of the moving dot, and mastering the giving of the coordinates required from 2 to 51 repetitions of the program. Comparison of the average indicators characterizing the speed with which the aforementioned components of the structure of operator activity were mastered shows that these tasks were not equal in difficulty. Thus, mastering the control skills turned out to be most difficult, requiring about 43 repetitions on the average. The test subjects mastered the recognition of the trajectory considerably more quickly, after 35 repetitions on the /23

*Each program included scanning one of the trajectories of motion of a white point from the upper to the lower screen edge.

average, and the easiest task proved to be mastering the ability to monitor the dot's movement by giving the coordinates. This [illegible] required 22 repetitions on the average.

Thus, the average indicators indicate that mastering the various components of the structure of operator activity involves the expenditure of different amounts of time and represents tasks of unequal difficulty.

The data obtained indicate that for six of our tests subjects [illegible] formation and automation of the control skills involved great difficulties. Despite a large number of repetitions, they did not succeed in developing sufficiently stable sensomotor coordinations. It was characteristic of these test subjects that they experienced similar difficulties in their daily lives. For example, in a conversation with the experimenter, test subject B. A. said that he had taken a driver-training course. He was successful in mastering the necessary theoretical knowledge, but he was unable to pass the driving tests because of inadequate sensomotor skills required for driving an automobile, despite a long period of training. On the other hand, this test subject very quickly, after four repetitions, began to give the coordinates correctly, and he successfully mastered in a short time the ability to recognize the form of the trajectory of the white dot. These facts indicate once again that mastering the different components of the structure of operational skills and abilities makes unequal demands on a person and consequently involves different aptitudes.

Analysis and summarization of the experimental data obtained make it possible to move toward ascertaining certain specific features of the operator's thinking processes involved in his recognition of visual images. Thus, analysis of the record sheets, which, in addition to the objective indicators, also recorded the data from the test subjects' verbal statements, showed that formation of /24 the ability to identify the trajectory of the white dot by observing its movements on the screen involves a gradual shift by the test subjects to more and more refined methods of receiving and processing information.

At the beginning of the training, the test subjects usually used the not very productive technique of superposition or sequential comparison of both the significant and the secondary individual attributes of the image pictured by them with the attributes of the standard trajectories. Use of this method of accomplishing perceptual tasks, given a limited amount of time, most often led to delayed reactions and to an inadequate assessment of the existing situation. As the training proceeded, the test subjects usually shifted to more effective unified methods of analyzing and processing information. The essence of these techniques consisted in the test subjects assigning each curve a name, e. g. "humped," "broken," "concave," etc. These names reflected the most characteristic totality of the image's static attributes. In the majority of cases, adoption of these unified attributes as guides made it possible to solve the recognition problems considerably more quickly and without error, without resort to sequential comparison of all the attributes of the image with the attributes of the standard trajectory.

In the process of solving these problems, the test subjects began to put forward hypotheses, which they verified in the course of subsequent analysis of the incoming information. For example, in observing the movement of the dot, one of the test subjects at first conjectured: "This is probably a broken trajectory?" Continuing his observations, he confirmed his hypothesis with the word, "yes" and then quickly and confidently pulled the appropriate tumbler switch. What has been said indicates that the problem-solving process takes on a clearly manifested hypothetical character. Usually the test subjects strive, on the basis of a summarization of current primary information, to put forward a hypothesis concerning the kind of trajectory that they see. These suppositions are subsequently verified in the process of observing the course of events. Verifying these hypotheses makes it necessary to obtain redundant information; therefore, the process of identifying the image proceeds at a retarded rate.

The correctness of this conclusion may be demonstrated by a more detailed elucidation of the question of the amount of information necessary for adequate identification of the forms of the trajectories. The forms of the trajectories used were selected so that revealing the first 20% of them provided all the information necessary for recognizing them. As the movement of the dot continued, the information concerning the attributes of its trajectory was repeated. This is because each of the standard curves had a periodic form that was close to a sinusoid. /25

When the test subjects used the hypothetical techniques for identifying the forms, this process usually required that 38% to 55% of the trajectory be revealed. This means that the amount of information provided exceeded by approximately 2 — 2.5 times the minimum that was necessary for adequate differentiation and recognition of the form of the trajectory.

The experimental data that we obtained also indicate that in the process of further training some of our test subjects gradually shifted from hypothetical, probability judgements for purposes of assessment to more economical and productive thinking techniques. Usually this shift came at the end of the training, when they had amassed sufficient experience in solving problems of this kind. They stopped speaking aloud their suppositions and tried to concentrate all their attention on grasping, when the form was first being revealed, and singling out the process of observation, dynamic combinations of attributes that were previously known to them and that could be used to recognize the form. When he had established the presence of these attributes, the test subject immediately moved to act. The image was recognized on the basis of particular attributes, for example: "If the dot first moves along a convex curve and then begins to drop vertically downward, that means that it is curve Number 3." Use of guidelines of this kind, which reflect the dynamic relationships of the significant attributes of the image, almost excludes the possibility of error and enabled the test subjects to identify quickly the form of the dot's trajectory. The mastering by the test subjects of more refined methods for

processing incoming information involved the use of similar techniques for analyzing and summarizing this information.

What has been said makes it possible to assume that improving the techniques for identifying the images is inseparably connected with the formation of unified conceptual ideas, in which the image is represented by a chain of events that has its own logical and dynamic structure.

Singling out and summarizing the dynamic relationships and the most characteristic attributes of this structure enabled the test subjects to find reliable criteria for rapid and adequate identification of the images.

It should be noted that the development of more refined /26
methods of solving these perceptual problems proved to be within the capabilities of only 7 of the 20 test subjects who participated in the first series of experiments.

The instances that we found in our study of the gradual shift by the test subjects from elementary and not very productive techniques of processing information to more and more reliable, unified, condensed, and effective methods of solving these perceptual problems may be taken into account in training operators for any kind of work.

In analyzing the data obtained from the first series of experiments, we found that the speed with which the image was revealed had an effect on how successfully it was identified. Thus, it was established that at very slow revealing speeds, from 1 to 5 mm/sec., the test subjects experienced difficulties in identifying the form of the trajectory. At the same time, equal difficulties were experienced when the image was revealed at a speed exceeding 20 mm/sec. Conditions were most favorable when the image was revealed at a speed of 10 to 15 mm/sec. Therefore, in our experiments the speed at which the images were revealed was equal to 12 mm/sec.

The study clearly showed the regulating role of the image both in the performance of the control functions and in the test subjects' development of a strategy for their actions. It was observed that the majority of the test subjects, after identifying the image, usually reorganized the actions involved in regulation and control. These actions took on a more organized and purposeful character. Guided by a clear idea of the form of the trajectory of the white dot, the test subjects usually shifted to a strategy of anticipation.

Whereas before the test subjects identified the image, they moved the red dot, i. e., the dot that they controlled, after the white dot (the strategy of following and tracking), after they identified the form of the trajectory they usually shifted to a strategy of anticipation. Guided by a clear idea of the form of the trajectory, the operator seemingly forsaw the course of events: The red dot began to move ahead of the white dot, and at the end of the training certain test subjects proved to be capable of moving their dot with a lead of up to one-fourth of the length of the trajectory. The shift to the anticipatory strategy creates favorable conditions for performing the functions of regulating and monitoring the processes being controlled. In addition, this strategy frees the operator from the need to track the course of events continuously.

Naturally, the use of the anticipatory strategy speeded up /27
considerably the formation of the operational-monitoring abilities and opened up opportunities for successfully mastering work under conditions in which a limited amount of time is allotted for performing the program. The characteristics of actions involved in guessing the course of events in advance, characteristics that have been described in the works of S. G. Gellershtein, were clearly manifested in the case of the test subjects of this group.

In our experiments we discovered the following important fact: The overwhelming majority of the test subjects who did not use the anticipatory strategy at the beginning of the training began to use it after it was suggested by the experimenter. In our opinion, the

speed with which this technique is mastered may serve as one of the important indicators for predicting a person's reliability and fitness for performing operator functions.

Thus, it was established by the experiments that the test subjects' mastering of the ability to track the course of events quickly and correctly, to recognize the trend of their development, and to use the anticipatory strategy in their behavior plays an exceptionally important role in the successful mastering of other abilities and skills that are necessary for work at a control panel. This fact has given us grounds for believing that the formation of operator abilities should be started with training in the recognition of the forms of trajectories, and only after the test subjects have properly mastered this component of operator activity is it possible to proceed to exercises aimed at the formation of the sensomotor actions involved in controlling the system.

In order to verify this hypothesis, we carried out a second series of experiments, in which 20 persons took part and in which the recognition exercises were repeated until the test subject was capable of correctly recognizing the images within 25% of the time allotted for revealing them. When this level had been achieved, the training was switched to the formation of control skills, as well as the formation of the ability to determine and give the coordinates of the moving dot.

The results obtained from the second series are summarized in Table 2.

Comparison of the indicators presented in Tables 1 and 2 gives us ground for drawing the following conclusions.

The test subjects who took part in the first series of experiments required an average of 51.5 repetitions to master the ability to work at the panel. On the other hand, an average of 46.6 repetitions were required for this in the second series. Thus, about 10% of the training time was saved. An average of 34.25 for /28
the first training variant and an average of 34.65 for the second,

TABLE 2

SUMMARY TABLE OF THE DATA OBTAINED FROM THE SECOND SERIES OF EXPERIMENTS

No.	Test Subject	Number of repetitions required to develop the skills and abilities for executing control	giving the coordinates	identifying the images	Total number of repetitions of the program
1	Sh-n	8	13	27	35
2	Z-y	13	27	26	35
3	O-o	29	11	21	36
4	K-y	13	5	32	37
5	P-ov	19	34	35	39
6	K-ev	20	6	34	40
7	K-iv	28	8	19	41
8	Z-ko	7	4	30	41
9	Zh-y	10	18	24	44
10	Sh-ak	10	34	28	45
11	L-ev	13	21	38	48
12	B-an	14	42	38	49
13	P-yak	7	17	19	50
14	B-ev	20	35	40	51
15	B-ei	27	41	47	52
16	S-ov	5	38	39	54
17	K-ich	24	32	46	55
18	P-ol	19	14	53	59
19	K-l	21	3	40	61
20	L-yo	21	54	57	62
Arithmetic mean		22.15	22.35	34.65	46.6

i.e., an almost equal number of exercises, were required to master the ability to recognize the images. Consequently, the effectiveness of the two methods was almost equal with respect to the formation of the ability to recognize the forms of the trajectories. We obtain a similar picture when we compare the average number of repetitions required by the test subjects to master the ability to monitor the dot's trajectory and give its coordinates. This required 22.1 repetitions in the first series and 22.3 in the second. Thus, here too none of the methods that we used had any noticeable advantages. /29

A basic difference in the effectiveness of these methods was clearly manifested when we compared the indicators characterizing the speed of the formation of the sensomotor control skills. While the formation of these skills required an average 42.7 repetitions in the first series of experiments, an average of 22.1 repetitions, i. e., barely more than half, were required in the second series. This confirmed our supposition concerning the

positive effect of the ability adequately to recognize the forms of the trajectories on the formation of the control skills. It may be assumed that this is a manifestation of the regularities in forming sensomotor connections and making them automatic that have already been described in the psychological literature. For example, the studies done by V. V. Mistyuk, [20] N. G. Levandovsky, [21] Ye. A. Mileryan, [22] and others have shown that the formation of sensomotor production skills is accomplished with considerably greater success in those cases in which the test subject is familiar with the principle of the machine tool's operation or with the trend of development of the processes that control.

In concluding the comparison of the results obtained in the first and second series, we should note one other significant fact. Examination of the data presented in Tables 1 and 2 shows that during the training of the test subjects in the first series of experiments, six of them failed to develop sufficiently stable control skills, despite a large number of repetitions. On the other hand, in the second series of experiments only 2 subjects experienced difficulties in mastering this skill. This fact confirms once again the advantage of the training method used in the second series of experiments.

The experimental data set forth above make it possible for us to discover certain trends in and ways of improving the pupils' operative thinking in the training process that are important from our point of view. The instances found in our research of a gradual shift by the test subjects from elementary and not very productive techniques of processing information to increasingly unified, condensed, and effective methods of accomplishing cogitative tasks can be taken into account in training operators for any kind of production. This training can be set up so that the pupils can consciously and purposefully master the unified techniques and guide- /30
lines for solving recognition problems. Practical utilization of these techniques will enable them to master operational-monitoring abilities and skills in a shorter time.

Analysis of the results of the test subjects' activity aimed at definitely locating the moving white dot and at giving its coordinates has shown that the performance of these functions at the beginning of the training was usually accompanied by erroneous actions. There were various reasons for these errors. Most often the test subjects confused the buttons for the vertical and horizontal coordinates, with the result that the vertical coordinates were given by pressing the buttons for the horizontal coordinates, and vice versa.

In conversations with the test subjects, it was learned that errors of this kind were primarily due to irrational positioning of the buttons. The majority of the test subjects noted that it would have been considerably easier for them to work if the buttons for giving the "vertical" coordinates had been placed in a vertical row and the buttons for the "horizontal" coordinates in a horizontal row. However, analysis of the results of further training showed that with practice this factor gradually ceased to have an effect. The overwhelming majority of the test subjects mastered this work system fairly quickly and at the end of the training carried out the required monitoring actions almost without error.

Sometimes our test subjects made mistakes in reading and determining the indicators on the coordinate grid. The reasons for these errors were insufficient attentiveness and an inability to grasp the situation quickly. It was often possible to observe how the test subjects, in trying to help themselves to determine the coordinates, placed their index fingers at the spot where the white dot was located and then began to move it vertically and horizontally. As a result of these actions, the test subjects usually spoke aloud conclusions such as the following: "Five on the vertical and nine on the horizontal." After that they began to look for the buttons. It is characteristic that this kind of oral activity slowed down considerably the test subjects' reations. Often the three-second interval allotted for this purpose was not enough for them, and this led to omissions and errors.

The test subjects who gave the coordinates most adequately and promptly were those who spoke very little and moved immediately from sensory perception to motor actions. The presence of this characteristic in large part determined how successfully the work at the control panel was mastered. Sometimes we noted errors of a perseverative nature. In these cases the test subjects memorized /31 certain coordinates and then tried to give them with each new repetition. Usually this happened when the test subject was tired because of a long period of work at the control panel.

Analysis of the data obtained in the study indicates the existence of significant individual differences among our test subjects in their aptitude for mastering the vocation of operator. Thus, if we examine from this point of view the experimental data obtained, we can draw the following preliminary conclusion: Among the 40 test subjects who took part in the first and second series of experiments, it is possible to single out a group of especially capable subjects who mastered the ability to work at the control panel after 23 — 40 repetitions. There were 11 subjects in this group. There were 13 subjects with average aptitude (41 — 55 repetitions). The rest of the test subjects (16 individuals), who needed 56 or more repetitions for the training, were described by us as having a low aptitude for these kinds of activity. We also placed in this group eight subjects who were unable to master the control skills, despite a large number of repetitions.

While we regard as purely preliminary this division of our test subjects into groups with a high aptitude, average aptitude and low aptitude for mastering the vocation of operator, we must still emphasize the need for careful selection among the applicants to the educational institutions that provide vocational training for the specialists of this type.

The instances that have been found in our research of a gradual shift by the test subjects from elementary and not very productive techniques of processing information to increasingly unified, condensed, and effective methods of accomplishing cogitative tasks can be taken into account in the training for any kind of work.

At the same time, the psychological research presented in this work indicates that one of the optimum variants for forming operational-monitoring abilities consists in the gradual and sequential mastering by the pupils of all the basic structural elements of this kind of work activity. At the beginning of the training, the pupils first of all have to learn how to construct an adequate image or model of the situation, in the process of tracking the course of events. This will subsequently enable them correctly to grasp the current state of the system being controlled, to find out the possible trends in the development of events, to analyze the conditions of the tasks confronting them and to find ways to accomplish them successfully. /32 After that the pupils' attention is directed toward choosing a strategy and working out an operative plan for carrying out practical work actions.

Mastering the initial components of the structure creates favorable preconditions for developing the sensomotor abilities and skills necessary for successful performance of the control functions.

The automatic ability components that insure the required speed, accuracy and coordination in performing the work operations are formed at this stage of the training with the aid of purposeful, conscious and planned exercises. The final stage of the formation of operational-monitoring abilities involves the pupils' mastering of the techniques for effective monitoring and correction of the work actions that they perform.

Practical utilization of the training techniques described above makes it possible to form in a short time abilities involved in competently performing and monitoring work operations that are versatile, flexible, unified, and easily transferable to new conditions.

The systems-structural, personal approach that we have developed for studying the problem of the reliability of the operator's work is inseparably connected the psychological analysis of his basic working conditions.

3. The Operator's Basic Working Conditions

Psychological study of the operator's work makes it possible to distinguish the instructional-training, minimum, optimum, and extreme working conditions.

Instructional-training working conditions have the purpose of forming, entrenching and improving the vocational knowledge, abilities, and skills used in a given type of operator activity. The training program is usually carefully planned and is carried out using special training devices or actual units under the direction and supervision of an instructor, who is responsible for the actions of his charges. Instructional-training sessions are used to build and verify the combat readiness of pilots, drivers, and operators who operate radar, missile, and power installations and other technical systems.

Minimum work conditions exist when the operator is controlling /33
a highly automated system that is functioning normally. As the works of V. S. Genes and Yu. M. Modiyevsky [23] and other authors show, a flow of useful information that is not enough to keep the operator busy, the absence of the need to carry out urgent controlling actions, increased comfort, and the monotonous, trouble-free operation of automated devices often lead to a loss of vigilance and to a shift from a state of "operative rest" to a hypnotic state. As a result, it is observed that there is a breakdown in the connections between sensory perception of a situation, comprehension of the situation, decision making, and action.

The development of hypnotic states is accompanied by considerable delays in reacting to emergency signals, which naturally create the preconditions for breakdowns, emergencies, and catastrophes. Thus, a person's work under minimum working conditions involves a danger of partial or sometimes even a complete failure to perform the functions assigned to him.

Optimum working conditions are comfortable conditions. The automatic devices usually function normally. The person has to track the current state of the system that he is controlling and correct and regulate the parameters that show a tendency to go beyond the limits of the norm.

The situation is normal, and for the most part actions are carried out automatically on the level of skills at one's own pace. Stereotyped performance by the operator of his work actions proceeds in a strictly determined order, and his thinking is algorithmic in nature. The chief role in activity of this kind is played by skills that have been acquired previously by the operator and that function without intense attention and at a normal rate. The automatic performance of work actions makes it possible for the operator to deal with other matters without detriment to his basic activity.

Under optimum conditions, insignificant nervous-psychic expenditures are required to achieve the intermediate and final work goals. Usually work capacity is maintained for a long time and there are no gross failures, erroneous actions, breakdowns, disruptions, or other abnormalities.

Work under optimum working conditions does not make any heightened demands on the personality. The performance of the work is usually marked by sufficient reliability and optimum effectiveness; any specialist who has the necessary vocational knowledge, ability, and skills can handle the work.

Under extreme working conditions the demands made on the /34
intellectual and especially on the emotional-volitional spheres of the personality are sharply increased. Work in complex, responsible and unexpected situations requires that the operator have highly developed self-control and the ability not to submit to the effects of the most varied objective and subjective stress-factors, to analyze quickly the current state of the system that he is controlling in order to ascertain the causes of the trouble in its operation, to find in a short time ways of eliminating these causes,

to make decisions promptly and confidently, and to carry them out adequately, without hesitation or procrastination, by means of a definite system of work operations, while simultaneously monitoring the effectiveness of the steps that he takes.

The content and nature of the operator's thinking also undergo a qualitative change. Whereas under optimum working conditions he was able to use ready-made, stereotyped techniques for solving problems, the heuristic components of thinking, which involve the creative, nonstereotyped application of knowledge and skills for practical purposes, come to the fore in continuously changing, often unexpected and new stressful situations. Under continuously changing conditions of stress, the decisive role is played by the operator's emotional-volitional personal qualities, which are manifested in his ability at times when it is necessary, by means of nervous-psychic efforts of his will, to maintain the necessary level of work capacity, to be impervious to emotions and hindrances and, without becoming flustered, to find a way out of the existing situation.

The operator must have courage based on a highly developed sense of duty and of responsibility for his actions. Only when this is so will he be successful in achieving both the partial and the final work goals confronting him.

Thus, among the psychological factors that determine the quality, reliability and combat effectiveness of the operator, his intellectual and emotional-volitional characteristics play the leading and decisive role. Resourcefulness, imagination, imperviousness to hindrances, courage, persistence, and a highly developed sense of duty and of responsibility for his actions are the personal qualities on which depend the success, reliability and effectiveness of the specialist who controls any technical system. It should also be noted that these working conditions usually involve discomfort, which disrupts the normal conditions of work and rest. In prolonged and difficult emergency situations, psychic /35 and physical overloads borne for a long period of time reach the

limits beyond which there may ensue physical and nervous exhaustion and a total breakdown in operator acitvity. That is why the operator's ability to expend his strength economically and to use it up gradually and the maintenance of the necessary level of work capacity during the entire work period are of great importance for maintaining the operator's psychic health and work capacity.

General-technical abilities come to the fore under extremely working conditions. They are manifested in the worker's capacity to achieve successfully, under changing and difficult conditions, the goal that has been consciously posed for him, by means of the creative application of unified means and methods of performing the work. As automated components of abilities, skills continue to play an important role in the operator's activity, but one that is subordinate to abilities.

In this connection, we should examine in greater detail the nature of general-technical abilities and their interconnection with knowledge and skills.

In a person's work activity there is a dialectical unity among his knowledge abilities and skills. Depending on the nature and conditions of the performance of this activity, skills and abilities may play different roles. When there is a change in external circumstances and a person has to enter into new relationships with his environment and solve new problems, abilities are the leading form of activity. When the environment remains constant and working conditions are stable skills come to the fore.

All work abilities without exception are formed and function on the basis of active, conscious and purposeful practical utilization of a person's experience as represented in his knowledge and skills. This experience serves as the basis for organizing a definite system of mental and practical operations whose performance ensures the achievement of the goals previously posed. When the conditions of this activity change, making new and more complex demands on the person, his abilities are improved and become the means for achieving

new goals, for further developing his capabilities and for enriching him with new experience. When the external environment remains constant and an external stereotype of the conditions of activity is created, the methods of performing the individual work operations may become automatic and be transformed into a skill, which is qualitatively different from an ability and which functions within the general structure of abilities.

The creation of abilities may be based not only on methods of performing actions that a person has previously mastered, but also on the new work techniques that are discovered and mastered in the very process of mastering the ability. /36

What has been said above makes it possible to interpret an ability as a extraordinarily complex structural combination of sensory, intellectual, volitional, and emotional qualities of the personality that are formed and manifested in the course of the conscious, expedient, and successful execution of a system of perceptual, cogitative, mnemic, volitional, sensomotor, and other actions that insure the achievement of the goal of the activity that has been posed, under conditions that change as the acitivity proceeds.

The formation of abilities always involves the sensory, intellectual, motivational, volitional, and emotional spheres of the personality, invariably promoting, given proper methods of guidance, the inculcation of the personal qualities that find application in this kind of work activity.

General work abilities, like the set of personal characteristics, are manifested as well as formed in the process of performing activity organized in a certain manner. Specific features of such activity are consciousness, which is manifested both in posing the goal and in determining the connections between the conditions of the activity and the means of achieving this goal; these two operations are always carried out in accordance with a plan that has been drawn up beforehand. Therefore, planning, foreseeing the course of events and monitoring the performance of the work operations

are mandatory features of this kind of activity. Premeditation and willfulness in performing the actions, which is manifested in attention, are also among its distinguishing features. Inseparable unity among intellectual, perceptual and practical actions, creative and nonstereotyped application of knowledge and the organic combination of theory and practice are equally important characteristics of such activity. Closely connected with these features are intellectuality and progressiveness, which are manifested in the personality's tendency toward progressive development and self-improvement, which lead to the mastering of increasingly complex kinds of work. The existence of automated components — skills that function as part of the general structure of competent activity — is also inherent in every complex ability of any kind. Finally, the most characteristic and synthetic feature of general-technical abilities is their generalized nature, which is manifested in the variative adequacy of the methods for achieving the goal in relation to the changing conditions of the work activity.

Everything that has been said above concerning the demands that are made on the individual by extreme working conditions indicate /37 that the effectiveness and reliability of the operator are determined first of all by his possession of general-technical abilities, as well as the moral, volitional, emotional, and intellectual qualities necessary for working under stressful working conditions. In addition to discomfort and a severe time limitation, the normal performance of the operator's functions is complicated under these conditions by the sense of responsibility that results from the awareness that errors, procrastination, delays, and failures by the operator can bring about breakdowns, emergencies, catastrophes, and other undesirable consequences.

Extreme working conditions place the individual in circumstances qualitatively different from all other working conditions and make higher demands on the vocational capacities of the personality. By no means every person who successfully performs the operator functions under instructional, minimum, and optimum working conditions can meet these demands. That is why psychological study of the problem of increasing reliability and effectiveness must make plain the

interconnection between vocationally important aptitudes and personal qualities and must determine the degree of their influence on work capacity, as well as on the oeprator's behavior under stressful working conditions.

Taking this fact into account, we have in fact directed our efforts toward experimental and theoretical study of the psychology of the operator's work under the extreme working conditions. A necessary condition for the objective study of this kind of work is determining systems of the basic criteria that could be used to work out research methods and to define with the proper clarity the concrete aims of the research.

In organizing our research in the field of the psychology of the operator's work, we proceeded from the following system of basic parameters characterizing his work activity.

The basic integral indicator characterizing the level of an operator's competence and work capacity is the quality of his work activity, which is manifested in the perfection of the methods for performing work functions and in the quality of the products of the work.

Thus, psychological study of the quality of the operator's work /38 inevitably involves finding out the structure of his personality and ascertaining the components of his personality on whose presence and degree of development depends the quality of the operator's work in the system "man — machine." In this connection, one of the top-priority tasks in studying operator activity is developing a method for objectively assessing the quality of the operator's work. There are grounds for believing that the quality of the operator's work activity can be analyzed and given an overall assessment by using a definite system of points based on consideration of the degree of reliability, the level of effectiveness and the indicators of accuracy, versatility, flexibility and the speed with which he performs the structural functions, operations, work techniques and actions that taken together insure the achievement of both the intermediate and final work goals under the most

varied working conditions, and above all under extreme working conditions.

Effectiveness is one of the important indicators of the quality of the operator. Effectiveness should be understood as the productivity of the activity in relation to the nervous-psychic, physical, energy, material, and all other expenditures required to achieve the work goals. It is well known that depending on the worker's state, on the level of his vocational training and on the conditions and perfection of the techniques used to perform the work, the magnitude of the expenditures for achieving the very same work goals may be different. For example, in the case of an inexperienced driver, driving an automobile involves great stress and considerable nervous-psychic and physical loads, which inevitably leads to rapid fatigue and the loss of work capacity. On the other hand, an experienced driver is capable of staying behind the wheel for many hours, while maintaining a high level of work capacity and without getting tired.

Thus, changes in work capacity and the degree of fatigue are indirect signs that can be used to judge the level of the operator's effectiveness. At the same time, this parameter of the quality of the operator's work can be measured directly by judging the degree of perfection of the problem-solving strategies that he uses, how economical his techniques are and how accurately he performs the operations./

Reliability and effectiveness are also connected with the versatility of the operator's activity. Versatility should be understood as the total number of variants of the strategies, techniques and methods for performing the actions that each lead to the achievement of the work goal that has been posed. The /39
basic indicator of versatility in the operator's work is the number of solutions to the problem that he finds as a percentage of the maximum possible number of variants of the solutions, which is defined as 100%.

The next characteristic that determines the quality of work activity is its flexibility, which is manifested in the operator's capacity for promptly changing his strategy or method for performing actions, in accordance with changes in the working conditions. The time or speed of changing strategies in response to changes in the situation may serve as an indicator of flexibility.

The operator's work also has its temporal aspect, which is manifested in the speed with which he performs a given assignment or in his labor productivity per unit of time.

Thus, the quality of work activity may be characterized in terms of such basic parameters of this activity as reliability, effectiveness, versatility, flexibility, accuracy, and work pace. Everything that has been said above concerning the criteria for objective measurement of the quality of the operator's work opens up new prospects for the psychological study of this kind of work. These opportunities can be realized through a comparative study of the structural and functional features of operator activity under instructional-training, minimum, optimum, and extreme working conditions.

Reliability is one of the principal indicators of the quality or level of competence of the operator. Reliability should be understood as a person's capacity for maintaining optimum work parameters under extreme working conditions. A more detailed definition of this concept might take the following form: The reliability of the operator is a structural set of emotional, volitional, motivational, intellectual and other personal qualities that insure through their interaction a certain degree of probability that the performance of operator functions under different working conditions will be accurate, free of error, adequate to the existing situation, prompt and successful. /40

Thus, reliability may be expressed as a measure of the stability of the optimum level of work capacity under extreme working conditions. It follows from this that it is possible to make a quantitative measurement of the degree of reliability, with

the aid of special mathematical relationships that express the operator's reliability coefficient under given working conditions. The formulas for determining the reliability coefficient may be obtained by various means, and each element of the structure of operator activity has its own indicators of reliability. For example, the reliability of the functioning of the sensomotor element can be measured by computing the so-called control coefficient, which is the result of the ratio between the total time adequate for performing the actions and the total time for performing the program. The percentage relationship between erroneously and correctly performed intellectual operations, etc. may serve as an indicator of the reliability of the performance of intellectual functions.

It is natural to assume that success in the experimental study of the reliability of the performance by the operator of his functions depends, first, on the degree of adequacy of the criteria chosen by the researcher; second, on the extent to which the conditions of the experiment insure the possibility of objective measurement of reliability under optimum working conditions and of the changes in reliability that occur under extreme working conditions; third, in order to obtain sufficiently reliable data, it is necessary that the experiment has as participants a sufficient number of test subjects whose activity is positively motivated and models the structure of an operator's work under optimum and extreme working conditions; and fourth, for each of the parameters of quality it is possible to develop a system of nondimensional assessment scales that will make it possible to define in terms of a certain number of points how pronounced or significant a given characteristic is. The simplest way of creating such a system of assessments is through statistical treatment of the data obtained from testing a sufficient number of test operators under optimum and extreme working conditions. By ranking the test subjects according to each of the qualitative parameters and determining the boundaries of the octiles in the table of ranks, we obtain eight-point systems of relative assessments of the reliability, effectiveness, versatility, accuracy, flexibility, and speed in performing work operations under various working conditions. Statistical treatment of the data obtained from testing of the test operators makes it possible to construct variation

curves that reflect the character of the distribution of the data with respect to each of the qualitative attributes or parameters. Examination of the form of each of the curves obtained makes it possible to judge to what extent the given working conditions /41
correspond to human potentialities. At the same time, comparison of the variation curves obtained under optimum and extreme working conditions will make it possible to draw conclusions concerning the changes in the quality of work caused by stress-factors.

A general assessment of the quality of an operator's work can be made by finding the arithmetic-mean assessments produced for all the parameters. After that it is not impossible to establish, by using the methods of factorial analysis, definite weights for each of these parameters, so that these weights can be introduced into the formula for assessing quality in the form of correction coefficients.

The approach that has been formulated above for creating a system of measurements of the quality of an operator's work is not the only possible approach. There is another, probably more promising possibility for constructing a system of assessments, a possibility that involves the basic elements of the structure of operator activity. In this case a general assessment of work quality may be made by using certain formulas to reduce the assessments to points that characterize the quality of the performance of individual functions under both optimum and extreme working conditions.

It is obvious that along with the overall system for assessing quality, partial subsystems should be developed that are designed to measure the reliability, effectiveness, flexibility, and accuracy of the performance by the operator of each of the structural functions. Use of the systems-structural approach enables the researcher to obtain a more detailed picture of the changes in the quality of each structural element that are caused by the factors in which he is interested.

Statistical treatment of the data obtained in the process of experimental studies of this kind will make it possible to create a system of objective assessments of operator quality in terms of the criteria of reliability, accuracy, effectiveness, versatility, flexibility, and work pace.

What has been said indicates that it is genuinely possible to do experimental psychological studies of the problem of reliability that are based on a definite system of criteria that are synchronized with the structure of this activity and that are used for the purpose of a comparative study of the changes that occur in the reliability of the performance by the operator of his functions when there is a shift from optimum to stressful working conditions. We have concretized and developed the fundamental approaches described above, in an experimental study of the effect of the operator's emotional-volitional qualities on the reliability of his work.

4. An Experimental Study of Operator Reliability Under Conditions of Stress /42

The problem of the reliability of an operator who controls a complicated systems-technology complex is one of the most urgent but at the same time poorly studied problems of present-day labor psychology. The brief survey of the state of this problem that was given in the course of the preceding analysis shows that under extreme working conditions the reliability of the performance of operator functions depends above all on a person's emotional-volitional qualities, which are manifested in his capacity to resist the effect of subjective and objective emotiogenic factors and to maintain the level of work capacity that is necessary for successful performance of all the functions assigned to him.

In Soviet and foreign psychological literature there are a number of studies devoted to the emotional stability of the operator (T. T. Tzhamgarov, K. M. Gurevich, V. L. Marishchuk, V. V. Suvorov, K. K. Platonov, L. M. Rozet, G. F. Khlebnikov, V. I. Lebedev, and others). However, further study of this problem is complicated,

first, by the extraordinary complexity of emotions and their close intertwining with other psychic processes and states and, second, by the lack of sufficiently reliable methods for the objective study of emotional states in the process of a person's work activity.

The formulation and execution of our research were preceded by a considerable amount of work on developing a method adequate to the subject being studied. In foreign and in particular in American aviation psychology, a major role in the study of emotional states is played by psychiatric conversations and interveiws, which actually serve to assess not emotional stability so much as predisposition to various psychic distrubances. However, during the Second World War, American psychologists developed a number of simulation methods for assessing the emotional stability of candidates during the selection of aviation personnel (a test of manual stability under a psychic load, a test of aiming under a psychic load, the test of the chair "soaring" through the air, a confusing control test, etc.). However, these simulation tests did not exhibit sufficient reliability or noticeable predictive value.

Analysis of the simulation methods for assessing emotional stability developed by the American aviation psychologists leads to the conclusion that the main reasons for their low effectiveness are, first, using as emotiogenic factors stimuli that did not always evoke sufficiently strong emotional reactions and, second, /43 using as criteria of emotional stability indicators that show changes in vegetative and visceral functions, which as is well known, are weakly correlated with a person's emotional stability. For example, the considerable quickening of the pulse of cosmonauts (120 — 140 beats per minute) that has been observed at the time of launch overloads has by no means led to any erroneous actions on their part. Third, and last, in cases in which motor reactions were recorded in the course of the tests, their conditions did not provide for sufficiently complex and lively activity that would even roughly model an operator's work.

These same shortcomings are also inherent to one extent or another in the "fall test," a method for assessing emotional stability developed by K. K. Platonov and L. M. Rozet, [24] and in the method developed by the Ukraine Republic Scientific Research Institute of Psychology for testing the capacity for following a known principle and emotional stability.

The absence in both domestic and foreign psychology of sufficiently effective methods for assessing the reliability and emotional stability of operators made it necessary to develop a new, special method for this purpose. The solution of this problem was based on the following fundamental considerations.

Above all, it is necessary to use genuinely emotiogenic factors in the tests, factors that will have a sufficiently strong emotional effect on all test subjects without exception. As preliminary experiments showed, the emotional force of a given stimulus is determined not only by its own character, but mainly by the general conditions in which a person is placed during the tests. Thus, if the test subject is not engaged in any purposeful activity, an outside stimulus, no matter how strong, has a much smaller emotional effect than when it is applied under conditions in which the test subject is engaged in solving a complex and important problem. On the other hand, it is most advisable to judge the emotional stability of a test subject by the changes in acitvity already formed that are caused by the emotiogenic factors. We emphasize how important it is that the activity be already formed. This is one of the important conditions of stability, because if a /44
person is tested in the process of doing work that he has not sufficiently mastered, this fact acts as an additional emotiogenic factor, whose role would be impossible to take into account in each individual case.

On the basis of the data in the literature and proceeding from the propositions set forth at the beginning of this work, we assumed, first, that the method for experimental study of reliability in the face of stress-factors should be based on the performance of

activity based on sensomotor coordination; second, that it should model the conditions of a definite structural element of operator activity; third, that the study should cover all working conditions, i. e., should test operators under instructional, optimum, and extreme working conditions; and fourth, that conclusions dealing with emotional stability and reliability may be drawn on the basis of a comparison of the objective indicators characterizing the activity as well as the behavior of the test subjects under various working conditions.

As a result of a critical analysis and creative summerization of domestic and foreign experiments, we developed a new research method based on consideration of all the requirements enumerated above and aimed at the study of the reliability of the performance by the operator of the sensomotor functions of tracking and controlling under instructional, optimum, and extreme working conditions.

This method was put into practice with the aid of a machine that we developed especially for this purpose — the emocoordinometer, which automatically programmed the course of the tests and objectively recorded the results of the test subjects activity. The essence of tests carried out using the emocoordinometer is that the test subject, by manipulating the appropriate levers and pedals of the apparatus, had to move a view finder through an assigned curved target area. The movement of the view finder in the plane of the screen is accomplished by electric motors. The speed and direction of the view finder's vertical movement are determined by how the lever is slanted, and the speed and direction of its horizontal movement are determined by the position of the control pedals. By manipulating the control elements, the test subject could move the view finder in the plane of the screen along any trajectory with varying speed. Control of the view finder's movement through the medium of electric motors required rather precise and subtle coordinations, and the speed with which they were mastered may serve as an indicator of the test subjects' capacities for forming sensomotor skills.

The character of the test subjects' activity schematically models the structure of the sensomotor actions involved in controlling an airplane. /45

The study consisted of three series of experiments. In the first series of experiments the test subjects were taught how to work with the apparatus, in the second series optimum conditions were created for the performance of the sensomotor functions assigned to them, and in the third series these functions were performed under extreme working conditions.

The level of reliability or the reliability coefficient (R) was determined by comparing the indicators characterizing the effectiveness of the performance of the sensomotor functions under extreme conditions with the same indicators of effectiveness under optimum working conditions. As the basic indicator of work effectiveness we used the control coefficient, which was determined by dividing the time during which the view finder was within the curved target area by the total time spent on performing the assigned program. This coefficient could vary from 1 to 0.

By comparing the average values of the control coefficients obtained under optimum and extreme experimental conditions, we were able to draw conclusions concerning the changes in the reliability of the test subjects caused by the stress-factors. We used as stress-factors, first, painful electric shocks that were automatically applied to the test subjects every time the view finder moved outside the program target area, and second, a severe limitation on the time allotted for performing the assignments. The time was limited in the following manner: If the test subject's actions were not prompt, a shield began to close off the target area and thereby created the threat of a complete failure to perform the assigned task.

The emocoordinometer is an electromechanical apparatus that meets all the requirements of the method described above. The general appearance of the appartus is shown in Figure 3. The apparatus is mounted in a wooden frame that is partially covered with metal. The front of the apparatus has a window through which

Figure 3. The emocoordinometer. Test subject's panel.

the test subject observes the movement of the view finder that he controls (1) on the program screen (2). The window may be closed off by the shield (3). Remote control of the view finder is carried out with the aid of the pedals (4) and the lever (5), which are located in front of the seat (6). The front of the device also has sockets for switching on the electrodes that are used to apply the electric-skin stimuli.

The experimenter's panel is located at the back of the apparatus. At the center of this panel /46 is a switch that is used to regulate the sensitivity of the view finder control elements. Its indicator is a voltmeter. Above the switch there is a microamperemeter that measures the strength of the current of the electric-skin stimulus, which is determined by means of a regulator. A voltmeter serves to indicate the speed with which the shield moves. This speed is regulated with the aid of a rheostat located under the slanting face of the panel. The function of the tumbler switch is to change the direction in which the shield moves. A button is used to place the programming device in the initial (zero) position. This is indicated by a small light.

The upper part of the panel contains counters that keep track, respectively, of the time spent in performing the program, the time spent in controlling and the time of "errors," i. e., the time during which the view finder is outside the program target area. The program is started and stopped by means of buttons. A tumbler switch is used to change the speed with which the program is presented. The experimenter's panel also has a tumbler switch for turning on the system, a fuse, and an indicator that shows when the system is turned on.

The emocoordinometer consists of the following basic units: 1) the unit for programming the test process and monitoring its results; 2) the unit for controlling the view finder; 3) the unit for controlling the shield; and 4) the power unit. /47

With the aid of the emocoordinometer described above, first we did two series of experimental studies, in which a total of 228 candidates for admission to one of the Air Force's higher aviation academies took part. All of our test subjects underwent a medical examination and, with respect to the state of their health, were pronounced fit for military service.

It should also be noted that all of them had an interest in achieving the best results during the emocoordinometer tests, since their admission to the academy depended on this.

A positive attitude on the part of the test subjects, which is expressed in their desire, no matter what, to overcome difficulties and to achieve the highest work indicators, is, in our opinion, a necessary condition for the experimental study of phenomena of the emotional and volitional spheres of the personality. This is because when the proper interest is lacking, the test subjects may react to the stress-factors by totally refusing to take any further part in the experiments or by producing results that are obviously beneath their capabilities.

* * *

In the first series of experiments reliability was studied under the following conditions. First each test subject was familiarized with work on the apparatus and was given the following instructions: "On the screen you see a bright band that is the program target area, in which the view finder can move. The movement of the view finder is controlled by means of the lever and the pedals. When you move the lever away from you, the view finder moves upward, while moving the lever toward you lowers the view finder. By pressing on the right pedal, we move the view finder to the right, and by pressing on the left pedal we move it to

the left. The speed with which the view finder moves increases as the angle of deviation of the lever and the pedals increases. Your job is, by using the lever and the pedals, to move the view finder so as to keep it within the program target area as much as possible. Moving the view finder outside the program target area is recorded as an error. A certain amount of time is allotted for performing the separate parts of the assignment; therefore, you must pay attention to the switching on of the small colored light located in the band. The assignment must be performed while the small light located at the end of the section of the parth being covered is lit. You are also allowed to anticipate the program."] /48

When he was convinced that the instructions had been understood and mastered, the experimenter suggested that the test subject perform one traning exercise at a slower rate. After that the test subjects had to perform five exercises under optimum working conditions and five exercises under extreme working conditions, following identical programs.

In order to even out the initial data, we alternated the working conditions. Thus, the odd-numbered exercises (1, 3, 5, 7, and 9) were done under optimum conditions, while the performance of the even-numbered exercises (2, 4, 6, 8, 10) was complicated, first, by the effect of the electric shocks, which had a strength of 50 — 60 microamperes and which were applied to the test subjects every time the view finder went outside the program target area, and, second, by a severe limitation of the time for performing the assignments. This was effected by means of the moving shield, which threatened the test subject with the closing off of the target area and with complete failure to perform the assignment if he was not prompt in carrying out his actions.

Before performing these exercises, the test subjects were given the following instructions: "We shall now move on to the performance of a more complex assignment. You should move the view finder through the same target area as accurately as possible, since every time it moves outside the target area you will receive a rather strong electric shock. In addition, when you start to

perform the program a shield will be turned on, and this shield may close off the target band if you are not prompt in carrying out your actions. If that happens, you will have to perform the assignment blindly, which will lower your work indicators considerably and increase the time that the electric current is applied."

The indicators from the counters that recorded the total time for performing each exercise, the time during which the view finder was within the program target area and the time during which it was outside the target area were entered on the record sheets of the experiment. In addition, the record sheets contained data from observations of the behavior of the test subjects during the experiments. The basic indicator characterizing the test /49
subjects' success in performing their tasks was the control coefficient (r), which was computed by dividing the time (t) during which the view finder was within the program target area by the total time (T) spent on performing the entire program — $r = \frac{t}{T}$.

Conclusions with respect to the reliability of the test subjects were drawn on the basis of a comparison of the average values of the control coefficients obtained from the performance of the five exercises under optimum conditions $r_{(o)}$, with the average control coefficient taken from the five exercises performed under extreme working conditions $r_{(e)}$. The reliability indicator (R) was computed according to the formula $R = r_{(e)} - r_{(o)}$; the features of the behavior of the test subjects during the experiments were also taken into account.

Analysis and summarization of the experimental data obtained in the first series made it possible to divide our test subjects into three basic groups. The first of these consisted of those test subjects (41%) whose work capacity did not undergo substantial changes as a result of the shift from optimum to extreme working conditions and for whom the difference between the average values of the control coefficients was no more than $\pm 1/2\sigma$.

Among the test subjects of the second group (30%) the stress factors always caused a sharp drop in work capacity, down to and including complete failure to perform the assignments. The difference between the average control coefficients was always negative, and its absolute magnitude was less than $-1/2\sigma$.

The third group (29%) of participants in the experiment was marked by a progressive increase in their work capacity under conditions of stress. In this group the differences between the average tracking coefficients were always positive, and their absolute magnitude exceeded $+1/2\sigma$.

Constructing a histogram and frequencies polygon made it possible to show that the curve of the sequence distribution has a clearly expressed maximum, in relation to which the branches are arranged symmetrically. In its basic features the form of the distribution curve approximates a normal, i. e., a Gaussian, distribution, which is one of the proofs of the adequacy of the method that we used and of the reliability of the experimental data obtained.

At the same time, deeper analysis of the data contained in the record sheets showed the existence of definite connections between the character of the behavior of the test subjects under conditions of stress and the productivity of their work.

These studies made it possible to establish that emotional states may have different effects on a person's behavior. Thus, the most widespread form of behavior under extreme conditions was manifested in a general dragging, slowing down, constraint, impulsiveness, and tension in the performance by the test subjects of their functions. Usually they squeezed the control levers convulsively, bit their lips and grimaced; their attention was fixed on the view finder; and they reacted to the effect of the /50
emotiogenic factors in an extraordinarily impulsive and strong manner. Emotional manifestations of this kind have been described in the works of K. K. Platonov, T. T. Dzhamgarov, A. V. Marishchuk,

V. V. Suvorova, and other authors. We called the type of behavior described above — tense.

At the same time, as the data that we obtained show, emotional behavior may be manifested in a person's consciously avoiding the performance of his functions. A certain passivity and an effort to shield oneself from intervention in the course of events were observed in individual cases. As K. M. Gurevich has established, in emergency situations the operator sometimes has difficulty in organizing his mental activity; he stands or sits in a frozen posture for a long time, wipes his forehead, wrinkles his brows, attempts to procrastinate and tries to move a little further away from the control panel, in order to be free from the effect of the emotiogenic factors. This is a manifestation of the emotion of fear, which results in the domination of the instinct of self-preservation; the individual's behavior is characterized by cowardice. We called this type of behavior under conditions of stress cowardly.

The third type of emotional behavior, the "inhibited" type, is characterized by a complete inhibition of a person's actions, which is usually caused by emotiogenic, unusual and serious situations. Thus, we find in the work of K. M. Gurevich vivid descriptions of the behavior of a representative of this group. An experienced dispatcher in the Moscow power system who was notified of an emergency that had the potential of disrupting the power supply of very important government facilities sat down in a chair and continued to sit in it silently and completely numbed until the emergency was ended by other operators.

It was found in the course of the study that the clearest and most dangerous manifestation of a person's emotional instability is affective disruptions of activity, as a result of which he begins to act aggressively, senselessly and in an uncontrolled manner. Under the influence of affect, the operator usually aggravates the state of the system that he is controlling, thereby accelerating the

the onset of catastrophes and emergencies. We called this type of behavior aggressive-uncontrolled.

At the same time, the data obtained indicate that there is a category of people who, given the proper motivation, significantly improve their work indicators when they are in an emotional state; this is the progressive type of behavior. The behavior of these test subjects was characterized by a fighting spirit, heightened tonus, minimum expenditure of strength and insignificant fatigue. The majority of them worked easily, without constraint and cheerfully took pleasure in their work. /51

The aim of the second series of our studies was to ascertain the nature of the effect of emotional states on the development and functioning of a dynamic stereotype. Therefore, an automatic sensomotor skill for working on the emocoordinometer was formed under instructional training work conditions. The test subjects performed the exercises on this instrument until their achieved automatic performance of the actions and the control coefficient reached a magnitude of 0.8. The number of exercises necessary to achieve this exercise indicator and the control coefficients for each exercise, as well as the results of the observations of the test subjects' behavior during the experiment, were recorded on the record sheets of the study.

Thus, formation of sensomotor skills was the basic content of the second series of experiments.

The third series of experiments was devoted to study of the reliability of the functioning of these skills under extreme working conditions.

In this series the test subjects performed the same assignments, but now every time that the view finder moved outside the target area the electric-skin stimulus was applied to them with varying intensity. In addition, at the start of the performance of each exercise the shield was turned on; its movement severely limited

the time for performing the assignments and threatened to close off the target area, which would bring about a complete failure.

At the beginning of the experiments the test subjects were individually familiarized with work on the emocoordinometer, and then they were given the appropriate instructions.

The readings of the counters that recorded the number of exercises, the total time for performing each exercise and the magnitudes of the control coefficient were entered on the record sheets of the experiment. In addition, a special column on the record sheets contained the data from the observations of the test subjects' behavior during the experiment.

The third series of experiments was aimed at studying the changes caused by the emotiogenic factors in the functioning of the skills that our test subjects had formed during the second series of experiments. The test subjects performed the usual exercises. However, the time for performing them was severely limited by the shield that moved over the target area. In addition, every time the view finder moved outside the target area the test subjects were subjected to the electric current. /52

The third series of experiments consisted of ten exercises. The first exercise was performed without the use of the emotiogenic factors. Then three test exercises were performed with the current at minimum strength — 25 microamperes. For the next three exercises the strength of the electric-skin stimulus (ESS) was doubled to 50 microamperes, and finally for the last three experiments the strength of the current was increased ot 75 - 100 microamperes.

Before performing these exercises, the test subjects were given the following instructions: "Now we move on to the performance of a more complex assignment. You should move the view finder as accurately as possible in the same target area, since every time that it moves outside this area you will receive a rather strong el

electric shock. In addition, at the start of the performance of the program a shield will be turned on, and this shield may close off the target area if you do not perform your actions promptly. If that happens, you will have to perform the assignment blindly, which will lower your work indicators considerably and will increase the time during which the electric current is applied." Along with the objective indicators characterizing the successfulness of the test subjects' work, the record sheets of this series of experiments also recorded the results of the observations of their behavior under conditions in which they were subjected to the emotiogenic factors. In addition, there were conversations with each of the test subjects aimed at ascertaining the difficulties that they encountered and at obtaining data concerning self-control and self-evaluation of the psychic states that they experienced.

Analysis and summarization of the data obtained from the second series of experiments clearly showed that for the overwhelming majority of our test subjects the initial period of forming their skills for working on the emocoordinometer involved the appearance of emotional states. It may be assumed that these states appeared as a reaction to the necessity of functioning under new, unusual, and rather difficult conditions. Mastering the sensomotor coordinations required appropriate volitional efforts and proper organization of the actions involved in control.

As I. P. Pavlov observed, the development of a dynamic stereotype is one of the basic conditions for the appearance of emotions. The appearance of emotional states in our experiment was proved by the presence of such specific indicators as tension, haphazardness, impulsiveness, and constraint in performing the work movements, squeezing of the control levers, unnatural posture, movement of facial muscles (biting lips and tongue) and focusing of /53 attention on the control elements in the case of certain test subjects; verbal emotional reactions were also observed.

In the conversations with the test subjects it was learned that they found the initial exercises especially difficult. They

tried to move the view finder as accurately as possible within the target area, and when they were not successful in this they felt annoyance, impatience, and a desire to achieve better results.

The exercise curves that we constructed also served as an objective criterion of the effect of emotions. It is characteristic that the initial sections of these curves are very similar for different test subjects and contain sharp rises and falls that reflect the considerable spread of the magnitudes of the control coefficients during the initial stages of the training. However, as the training proceeded further, individual differences both in emotional behavior and in the course of the formation by our test subjects of the sensomotor skills began to come out more and more. In this connection, we should turn first of all to the table of ranks presented below, in which our test subjects are ranked /54 according to the number of exercises that they needed in order to form the sensomotor coordinations (Table 3).

Examination of the data presented in the table shows that from 23 to 78 exercises were required to form the sensomotor skills. The broad range of the spread of these indicators indicates considerable individual differences in aptitudes for mastering sensomotor skills. This fact is well known and has been confirmed by many researchers. However, we were interested in the question of whether there is a definite relationship between the emotional state of the test subjects and the speed with which they perform the skills. We can find the answer to this question by comparing the exercise graphs that characterize the work of the test subjects who fall into the first and fourth quartiles.

It was characteristic of the overwhelming majority of the test subjects in the first group, who needed from 23 to 36 repetitions to master the skill, that emotional states appeared only during the initial period of skill formation. But after 15 to 25 exercises the signs of emotion disappeared, their activity became more and more automatic and their behavior became calm, confident, adequate, and successful.

TABLE 3

TABLE OF RANKS ACCORDING TO THE NUMBER OF REPETITIONS REQUIRED TO FORM THE SENSOMOTOR SKILL

No.	Test subject	Number of repetitions	Absolute rank	Relative rank	Quartile
1	Z. V.	23	1	1	
2	B. I.	24	2	2	
3	P. I.	25	3	3	
4	T. V.	29	4	4	
5	T. V.	31	5	5	I
6	T. V.	32	6	6	
7	L. A.	36	7)		
8	Ch. A.	36	8)	8	
9	Zh. I.	36	9)		
10	T. V.	39	10	10	
11	Ya. V.	41	11	11	
12	D. S.	42	12)	12.5	II
13	B. N.	42	13)		
14	B. V.	44	14	14	
15	B. A.	45	15	15	
16	M. S.	48	16	16	
17	Ch. V.	50	17	17	
18	M. I.	51	18	18	
19	Ye. P.	52	19	19	III
20	M. M.	58	20)	20.5	
21	P. Yu.	58	21)		
22	L. M.	64	22)		
23	B. A.	64	23)	23	
24	K. V.	64	24)		
25	S. V.	66	25)	25.5	IV
26	M. S.	66	26)		
27	M. V.	73	27	27	
28	R. A.	78	28	28	

The graphs of the test subjects indicate that they progressed from exercise to exercise and quickly reached the assigned level of work effectiveness.

Figure 4 shows an exercise graph that is typical of this group (test subject B. I.). It may be clearly seen in this graph that at the start of the training this test subject showed sharp and sudden changes in the indicators characterizing the success of his work on the emocoordinometer. For example, his tracking coefficient during the performance of the third exercise was equal to 0.5, but during the fifth exercise it fell to 0.2, etc.

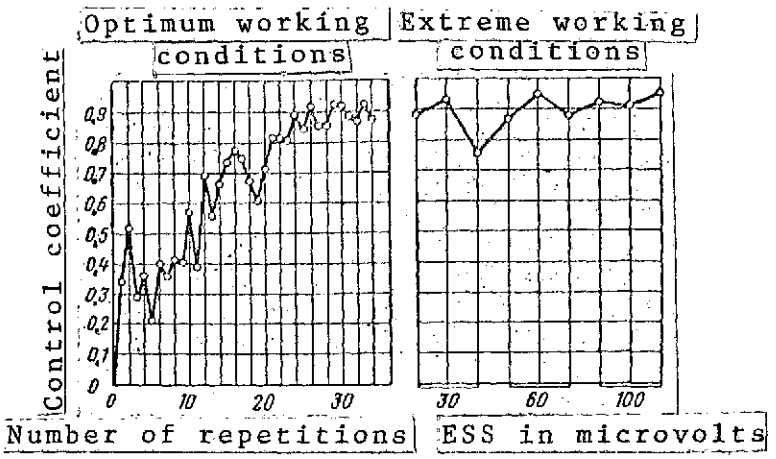


Figure 4. Curves of the formation and functioning of the sensomotor skill, in the case of test subject B. I., under optimum and extreme working conditions.

Alternation of significant peaks and falls is observed right up to the 21st exercise, after which the character of the curve changes and it shows a steady trend toward progress, with insignificant fluctuations.

By comparing the form of individual sections of the curve that we are examining with the data from the observations of the behavior of test subject B. I. that are recorded on the record sheets, it is not difficult to demonstrate that during the initial training period the sharp variations in the successfulness of his work were inseparably connected with his emotional state. Thus, in the record /55
sheets of experiments Numbers 1, 2, and 3 we find the following description of his behavior: "He works tensely and at a retarded rate, bites his lips and frowns; his attention is fixed on the view finder. When he makes mistakes, he expresses aloud his dissatisfaction." But after the first 20 exercises have been performed, the behavior of the test subject becomes more and more confident, calm, and unconstrained. He tries as much as possible to work without hurrying and without making mistakes. Thus, in this case the signs that are characteristic of emotional states gradually disappear as the skill is mastered, and behavior becomes more and more automatic, stable, and effective.

We placed in the second group those test subjects whose indicators were between 39 and 48 repetitions (the area of the median of the table of ranks). Finally, the third group consisted of the test subjects who needed 60 or more exercises to form the sensomotor skill. A characteristic feature of the work and behavior of the members of this group was sharp fluctuations in the exercise curve throughout the training.

Figure 5 shows the exercise curve of one of the members of this groups, test subject M. V., who needed 73 repetitions in order to master the skill. In examining the exercise curve, one can easily see that during the experimental training the work indicators of this test subject fluctuate considerably, and the results of the observations of the test subject's behavior that are recorded on the record sheets indicate that his emotional states maintained their strength up to the end of the training. Thus, it is recorded on the record sheets (60^{th} — 73^{rd} exercises) that the skill is being developed very slowly, unevenly, and erratically. The test subject becomes flustered, hurries, makes mistakes, works without confidence /56 and impulsively, moves his lips and is very tense.

Comparison of the results characterizing skill formation by the test subjects that we placed in the first and third groups gives us grounds for believing that one of the principal reasons for the considerable lagging of the members of the third group is the unceasing effect of their emotional states, which help to make the dynamic stereotypes automatic at the beginning of the training but later hinder this process. This fact indicates that a person's emotional stability may be determined in the process of his training. The speed with which he adapts to the effect of the emotiogenic factors may serve as the chief indicator of his emotional stability. Emotions inevitably appear when a person is mastering a new activity that requires that difficulties be overcome. However, with practice under stereotyped conditions the emotional states gradually disappear as the dynamic stereotypes become automatic, and the activity at the skill level becomes stable, reliable, impervious to hindrances.

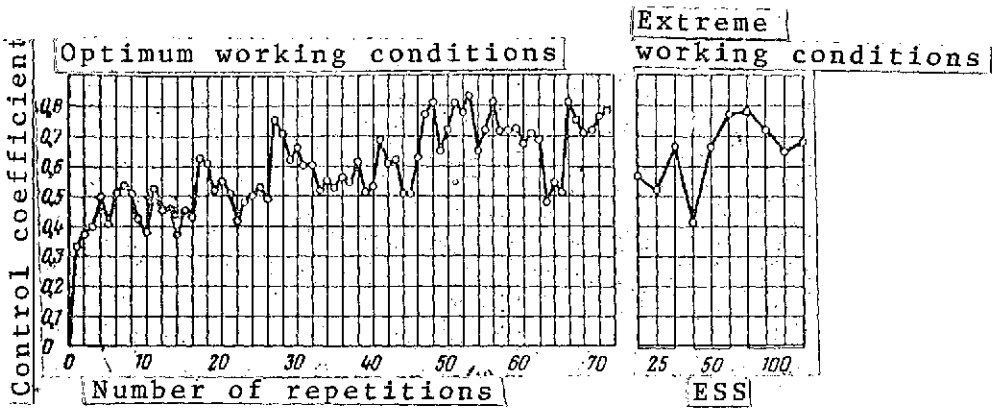


Figure 5. Curves of the formation and functioning of the sensomotor skill, in the case of test subject M. V., under optimum and extreme working conditions.

As Ye. I. Boyko observes, it is well known that a skill is characterized by "decreased sensitivity to hindrances and distracting circumstances of any kind." [25] In our opinion, the reason for this is that an activity that has become automatic does not require attention and can be performed in the inhibited segments and sections of the brain, which are located outside the dominant.

The study has shown that emotiogenic factors can have different /57 effects on the development and functioning of automated actions. Thus, during the first stages of training in the skills, emotional states play an extraordinarily important positive role. As the dynamic stereotype becomes automatic, emotional states may act as a hindrance that reduces work activity and sometimes even disrupts it completely. With the aim of experimental verification of this hypothesis, in the third series of experiments we studied the functioning of the sensomotor skills that had been developed in the second series, under conditions in which the test subjects were subjected to emotiogenic stimuli of varying intensity and modality. Twenty-eight of the test subjects who had succeeded in developing the sensomotor skill of working on the emocoordinometer took part in this series of the experiments.

Summarization of the data obtained from the third series of experiments has made it possible to establish a number of new facts that reveal the psychological regularities involved in the interaction of the emotional-volitional components of work behavior. With this aim in mind, we compared the results characterizing the formation of sensomotor skills by each test subject with his work indicators under conditions in which he was subjected to the emotiogenic factors. As a rule, in the case of the majority of the test subjects the first applications of the emotiogenic factors were accompanied by a significant drop in the quality of their work. Thus, during the performance of the first exercises, which was accompanied by an ESS of minimum strength (25 microamperes), the control coefficients of 24 test subjects fell from 0.8 — 0.9 to 0.7 — 0.6. For this group the drop in the test subject's work effectiveness was manifested by an average decrease in these coefficients of 0.16. However, as the training proceeded and we shifted to stronger electric-skin stimuli (with a strength of 50 microamperes), the success indicators improved considerably in the case of most of our test subjects. For example, it may be clearly seen in Figure 6 that during the first three exercises performed by test subject Ch. A., the moving shield and an ESS of 25 microamperes caused a drop in the coefficient (r) from 0.91 to 0.6 in the first exercise, and then in the second exercise this coefficient rose to 0.85. We observe an even greater increase when the ESS is increased to 50 microamperes. However, further increases in the strength of the electric-skin stimulus lead to a sharp increase in the number of errors and to a decrease in the coefficient (r) in the last (ninth) exercise to 0.65. Thus, this case clearly manifests what is in our view a very interesting regularity regarding the /58
effect of the intensity of the operating emotiogenic factor on a person's work effectiveness. It is obvious that for each person there is an optimum intensity of the emotiogenic factor under which he works most effectively.

In all probability, this confirms the rule advanced at one time by Jereks and Dodson [26]: There is a certain optimum emotional tension for the most successful performance of every assignment.

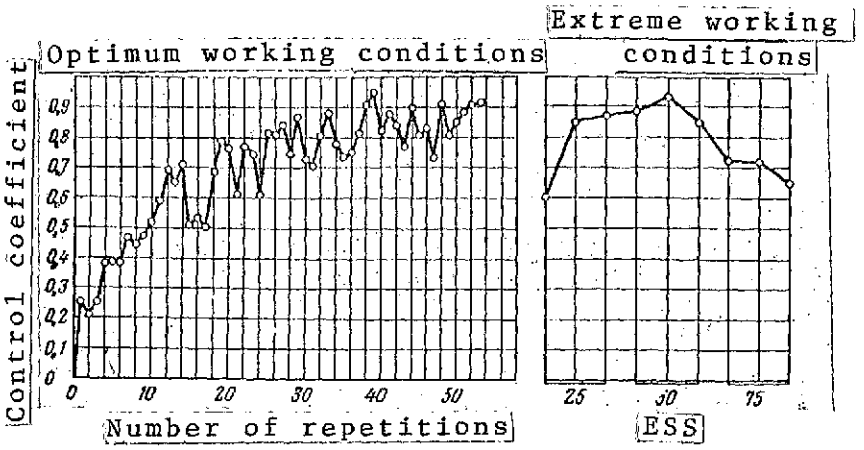


Figure 6. Curve of the formation of the sensomotor skill, in the case of test subject Ch. A., under optimum and extreme working conditions.

According to the Jereks-Dodson principle, work effectiveness depends on the degree of emotional tension, and the effectiveness of the performance of a certain kind of work reaches a maximum only when there is a certain level of emotional tension. Any change in this tension in any direction is accompanied by a drop in work effectiveness.

When we examine, from this point of view, the experimental data obtained, we are convinced of the correctness of this supposition. The exercise curves obtained for the majority of test subjects have peaks that appear when the ESS is applied with one or another intensity. For some test subjects these rises in the curve appear at 25 microamperes, for others they appear when the intensity is 50 and for still others when the intensity is 75. At the same time, the experiments showed that when one shifts to very high, ultra-ESS intensities, complete disruption of the work ensues. In our reserach we succeeded in bringing about such disruptions of activity by increasing the strength of the ESS to more than 100 microamperes. /59

Thus, in light of the data obtained, the emotional tension that appears both during the development of dynamic stereotypes and during their functioning under extreme working conditions is one of

the basic factors that determines the operator's reliability and work capacity. This constitutes experimental confirmation of the following psychological regularity, which has been formulated in the works of Academician B. G. Ananyev: "Emotional tension is the core of work capacity."

In this connection, we should emphasize the extraordinarily important role of the operator's emotional states, which influence his effectiveness and reliability in performing his assigned functions under new and unusual working conditions that involve overcoming all kinds of difficulties. In this regard, for each person there is an optimum level of outside, obstructing factors, at which the psychophysiological potentialities of his work capacity are best realized.

Analysis of the record sheets of the conversations held with the test subjects showed that for 16 of our pupils, the threat created by the moving shield was a more powerful emotiogenic factor than the pain caused by the electric-skin stimulus. For example, in the conversation with test subject Zh. I. it was learned that he was hindered most in his work by the threat created by the moving screen, while the ESS helped him during the initial exercises to know better whether his actions were correct. However, after the ESS had been increased to 100 microamperes, this test subject no longer observed the movement of the screen, his work indicators dropped sharply and he complained of being tired and of the excessive tension connected with the need to mobilize himself to overcome the effects of the emotiogenic factors.

The ESS had a considerably greater emotional effect than the screen on 11 of our test subjects. Two of them had higher emotional sensitivity; therefore, they refused to work when the strength of the ESS exceeded 50 — 70 microamperes. The record sheet for test subject L. M. exemplifies this very well. The graph (Figure 7) shows the exercise curve characterizing the work of this test subject during the first series of experiments. This curve indicates that /60
L. M.'s emotional states affected him throughout the training period.

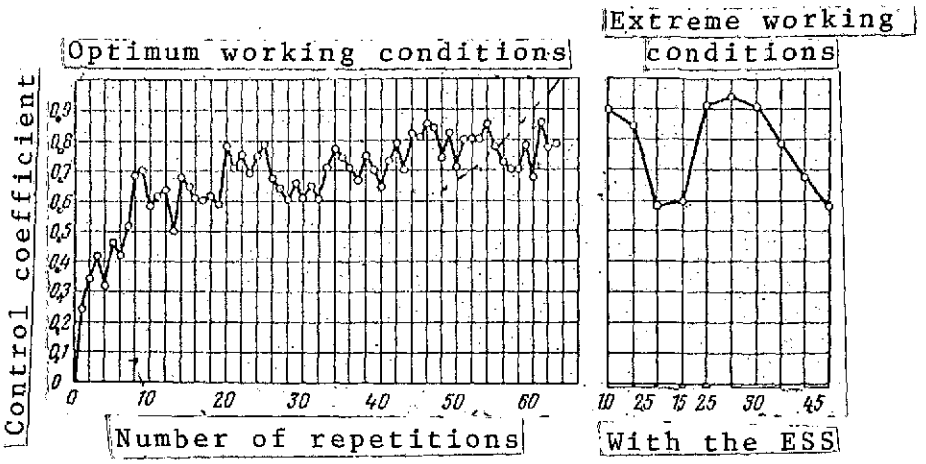


Figure 7. a) Curve of the formation of the sensomotor skill under optimum working conditions; b) Curve of the functioning of the sensomotor skill under extreme working conditions. Test subject L. M.

This test subject occupies one of the last places in the table of ranks. During the second series of experiments he reacted to an ESS of minimum strength (25 microamperes) with severe agitation and shaking and by squeezing his hands convulsively, sticking out his tongue and asking that the strength of the stimulus be reduced, since he could not stand the pain. He complained of excessive weariness when working. When the strength of the stimulus was increased (40 — 50)microamperes), complete disruption of his activity ensued. L. M. refused to work and became emotionally upset; he shuddered, his hands became numb, his face turned red, and his movements were impulsive and chaotic.

Comparison of the exercise curves obtained from the second and third series of experiments shows that the speed of adaptation to new conditions of activity is inseparably connected with progress in forming sensomotor skills. It is characteristic of the work of emotionally stable test subjects under conditions of stress that their work indicators fall when they are first subjected to the emotional factors, and then this trend gives way to a steady increase in productivity in response to increases in the strength of the ESS, which is observed right up to certain magnitudes that are the optimum magnitudes for a given test subject. A further increase in the strength of the electric-skin stimulus leads to a steady decrease in the effectiveness of work actions.

It is characteristic of the test subjects who are emotionally stable and whose work is reliable that the strongest emotional factor at the beginning of the experiment is the threat created by the moving shield, and only when the strength of the ESS reaches 75 — 100 microamperes do the painful sensations caused by the electric-skin stimulus come to the fore. /61

During the first series of experiments the test subjects who are emotionally unstable and not very reliable needed a considerably greater number of repetitions in order to form the sensomotor skill, and the exercise curve and the data recorded in the record sheets indicate that emotional states affected them throughout the training. Under conditions in which they were subjected to the emotiogenic factors, these test subjects showed an uneven and sudden increase in the number of errors with each rise in the strength of the ESS.

In the case of these test subjects the curve of the effectiveness of the functioning of the skill under conditions of stress shows irregular, chaotic fluctuations without a clearly expressed optimum. An increase in the strength of the ESS to 70 — 100 microamperes brought about sharp drops in the curve, which sometimes fell all the way to complete affective disruptions of activity. The attention of the emotionally unstable test subjects was mainly directed toward the ESS.

Statistical treatment of the data obtained from the second and third series of the experiments has made it possible for us to establish the existence of definite relationships between the speed of sensomotor skill formation and the emotional stability of our test subjects. Thus, on the basis of the results of ranking of test subjects according to the indicators obtained from the first series of experiments, we divided them into three groups. The first consisted of 9 subjects who needed from 23 to 36 exercises to form the skills. The 12 test subjects (from 39 to 60 exercises) who occupied places in the area of the median (the second and third quartiles) were placed in the second group. Finally, the third

group was made up of those test subjects who fell into the fourth quartile and needed more than 60 repetitions.

The results of comparing the success indicators from the second and third series of the experiments are presented in Table 4.

When one examines the data that are presented, one can easily see that 45% of the test subjects who produced the best indicators during the first series of experiments improved their work when they were subjected to the emotiogenic factors, while no substantial changes were observed in the work of 55% of these subjects under these conditions, i. e., all of them proved to be emotionally stable. At the same time, among the test subjects from whom skill formation had been difficult (the third group), 71.4% proved to be emotionally unstable and only 28.6% showed sufficient stability in their work. No less significant is the fact that the percentage of the test subjects of the second group falling into each of the three categories was 33% in each case. Thus, analysis and summarization of the experimental data obtained clearly reveal the existence of a direct relationship between the speed with which dynamic stereotypes are formed and a person's emotional stability. Hence, we draw the important practical conclusion that a person's reliability and emotional stability under extreme working conditions can be predicted on the basis of the character of his exercise curve and the speed with which he forms sensomotor skills under instructional training working conditions. /62

What has been said gives us grounds for believing that when a person is subjected to outside hindrances, his work improves in those cases in which these hindrances act as a subdominant, intensifying the basic working dominant connected with the performance of the sensomotor actions. At the same time, the negative effect of the ESS may result from the appearance of subcortical dominants that divert to themselves the stimulation of the cortical centers and thereby reduce or completely disrupt the basic activity of the test subjects.

TABLE 4

Group, according to the results of the first series	Number of test subjects who improved their work indicators during the third series	%	Number of test subjects with stable work capacity during the second and third series	%	Number of test subjects whose work got worse under the affect of the screen and the ESS during the third series	%
I (1st quartile)	4	45	5	55	0	0
II (2nd and 3rd quartile)	4	33	4	33	4	33
III (4th quartile)	0	0	2	28.6	5	74.4

In a number of cases we encounter a struggle between the emotiogenic subcortical and cortical dominants, which is manifested in fluctuations in attention, volitional efforts, tension, impulsiveness, and behavior by the test subjects that meets with varying success.

In continuing our discussion of the experimental data obtained, it should be taken into account that the electric-skin stimulus evokes an unconditioned defensive reflex. Therefore, the ESS should /63 be regarded as an unconditioned emotiogenic stimulus that is addressed directly to the subcortical formations that deal with emotional states. Along with this, the threat created by the moving shield was a conditioned first-signal emotiogenic factor. Considering this fact, which is of no small importance, we may suppose that in the case of emotionally stable test subjects the conditioned emotiogenic factor comes to the fore, and the first-signal system is dominant and regulates the test subjects' emotional behavior. The predominance of the electric-skin stimulus in the case of the second group of test subjects may be viewed as one of the manifestations of the dominating role of the subcortical formations directly connected with emotions.

The principal aim of the next cycle of experimental research on operator reliability, which we carried out together with A. V. Solodkova, was the study of the nature of the interconnection between

the emotional-volitional components of a person's work activity under conditions of stress and changes in his vegetative functions. We organized this research because it was necessary to provide a clear answer to the question of to what extent reliability and work effectiveness are reflected by, and may be monitored according to changes in, the parameters characterizing the activity of the central nervous, cardiovascular, vegetative and endocrine systems.

In order to accomplish this aim, we used the emocoordinometer method to carry out two series of experiments, in which 27 test subjects aged 19 to 25 took part.

We began the experiments, which were done on an individual basis, by making the test subject generally familiar with the techniques of working on the emocoordinometer. For this purpose, each test subject performed two instructional-training exercises. After the subject had mastered the instructions, he was asked to perform 40 identical programs at his own pace. The principal aim of this series of experiments was to study the nature of the changes in the series of physiological functions described below, during the formation of sensomotor control skills.

At the start of the first series of experiments, the test subjects were given the following instructions:

"On the screen of the apparatus you see a bright band, which is the program target area, in which the view finder may be moved. The movement of the view finder is controlled by means of the levers and pedals. When you move the lever away from you, the view finder moves upward; when you move the lever toward you, it moves downward. When you press the right pedal, you move the view finder to the right, and when you press the left pedal you move it to the left. The speed with which the view finder moves increases as the angle of deviation of the lever and the pedals increases. Your job is to move the view finder within the program target area by using the lever and the pedals. Movement of the view finder outside the program target area is recorded as an error. Try to make as few errors as possible. Anticipating the program is permitted. /64

You will now be given the opportunity to master work on the apparatus and to practice. First familiarize yourself with the mechanisms for moving the view finder, and then calmly and as accurately as possible move the view finder from the initial to the final point. After practicing you will have to perform 40 test exercises."

When he was convinced that the test subject had understood and mastered the instructions, the experimenter turned on the apparatus by pressing the "on" button.

After the completion of each exercise, the experimenter entered on a record sheet the results of the tests as recorded by the counters: the total time for performing the program, the time for adequate control, and the total time of the test subject's erroneous actions. In addition, the record sheet of the tests contained both the data from objective observations of the test subject's behavior during the experiment (his tension, decisiveness, confusion, attentiveness, agitation, and the impulsiveness of his actions) and verbal statements (his state, reactions, feelings, sensations, etc.).

The record sheets also recorded data concerning the following: 1) pulse rate, which was measured every 10 minutes; 2) the amount of adrenaline, noradrenaline, and sugar isolated in the urine before and after the experiment; and 3) changes in the magnitudes of the systolic and diastolic arterial pressure.

The same test subjects took part in the second series of experiments, which was carried out under extreme working conditions. In contrast to the preceeding series of experiments, in this series the performance of the exercises was complicated by the effect of the following stress factors: a sonic stimulus with an intensity of up to 100 decibels, a shield that severely limited the time for performing the program and an electric-skin stimulus with a strength of 80 microamperes that was applied in response to each erroneous action by the test subject.

The instructions for the second series of experiments were as follows: "We shall now move on to the performance of a more complex assignment. You should perform the same 40 exercises as in the preceding experiment, but now every time that the view finder goes /65 outside the target area you will be subjected to an electric current. Try to work as accurately and as quickly as possible. In addition, at the start of the program a special shield will be turned on. It will gradually close off the screen and the target band. Your job is to move the view finder as accurately and as quickly as possible, while staying ahead of the shield. Otherwise, it will close off the target band and you will have to perform the assignment blindly, which will naturally increase the number of errors and the time during which the electric current is applied. Besides this, you will be subjected to rather strong sonic signals."

The integrated approach to study of problems of reliability that is being developed by our institute required that not only psychologists but also physiologists and physicians specializing in hygiene take part in the experiments. Therefore, our experiments were carried out in a special laboratory by a whole group of researchers who had experience in working in the fields of psychology, physiology, medicine, and hygiene as they are related to labor.

The treatment of the experimental data obtained was carried out with the aid of statistical, factorial, and correlation analyses.

We were of the opinion that it would be most convenient to begin the analysis and summarization of the experimental data obtained by putting into practice the methods of psychological assessment of reliability that were described at the beginning of this work.

After computing the average value of the control coefficient for the optimum and extreme series of experiments for each test subject, we used the formula $R = r_{(o)} - r_{(e)}$ to find the magnitude of his reliability coefficient R.

By ranking our test subjects according to their reliability coefficients, we obtained the table of ranks that is presented below (Table 5).

Overall statistical analysis of the data presented in the table of ranks, as well as construction of the distribution curve of the variant of the reliability indicator (R), enabled us to divide our test subjects into three basic groups.

The first group, which was conditionally called the "progressive" group, was made up of those test subjects who under extreme working conditions, increased their effectiveness and reliability in performing the sensomotor control functions. In the case of these test subjects, the reliability indicator R was positive and its absolute magnitude was greater than 0.04. As may be seen from the table, there were 13 such test subjects, which constitutes 48% of the total number of participants in the experiment.

The second group was made up of seven subjects (26%) who showed /66 relative stability in performing their operator functions under optimum and extreme working conditions. The values of R were close to zero. The absolute magnitude of the reliability indicator was within the limits of $\pm$0.04.

The work capacity of the test subjects in the third group, which consisted of seven persons (26%), dropped sharply under conditions of stress, right down to complete disruption of work activity.

When one compares the quantitative distribution of the test /67 subjects that we placed in the stable, progressive, and regressive groups on the basis of the results of the first and second cycles of the experiments (see Table 6), one can easily see that there is a certain discrepancy in the experimental data obtained. Thus, while this discrepancy is 19% for the progressing group which consists of those who improved their reliability indicators, the difference is equal to 15% for the test subjects whose work was stable. At the same time, the disparity in the data for the regressive group is 4%.

TABLE 5*

TABLE OF RANKS ACCORDING TO THE PARAMETER OF THE RELIABILITY OF THE PERFORMANCE OF SENSOMOTOR FUNCTIONS

No.	Test subject	$r_{(o)}$	$r_{(e)}$	R	%
1	A.G.	0,83	0,56	0,29	
2	L.O.	0,87	0,59	0,28	
3	G.O.	0,54	0,26	0,28	
4	V.V.	0,74	0,52	0,22	
5	V.A.	0,78	0,58	0,20	
6	D.M.	0,71	0,54	0,17	43
7	V.K.	0,65	0,48	0,17	
8	V.A.	0,65	0,49	0,16	
9	V.F.	0,71	0,55	0,16	
10	K.O.	0,62	0,50	0,12	
11	L.I.	0,66	0,54	0,12	
12	A.A.	0,50	0,43	0,07	
13	V.P.	0,71	0,66	0,05	
14	V.F.	0,57	0,53	0,04	
15	B.V.	0,77	0,76	0,01	
16	A.V.	0,85	0,84	0,01	26
17	Yu.O.	0,62	0,62	000	
18	S.P.	0,56	0,56	000	
19	O.K.	0,47	0,49	—0,02	
20	O.A.	0,66	0,70	—0,04	
21	V.I.	0,55	0,60	—0,05	
22	S.D.	0,62	0,70	—0,08	
23	Ye.A.	0,56	0,65	—0,09	
24	A.Yu.	0,46	0,55	—0,09	26
25	V.I.	0,60	0,72	—0,12	
26	Yu.B.	0,57	0,70	—0,13	
27	V.V.	0,39	0,58	—0,19	

In our view, these discrepancies are explained primarily by the difference in the conditions under which the tests were conducted. The first series of experiments comprised only 10 exercises. In this series the odd-numbered programs were performed under optimum working conditions, while the programs of the even-numbered exercises were performed under extreme working conditions. In contrast, the experimental results that we are analyzing were obtained from exercises performed many times (40 in each series of

*[Translator's Note: Commas in the numbers indicate decimal points.]

TABLE 6

PERCENTAGES MAKING UP THE GROUPS WITH DIFFERENT LEVELS OF WORK CAPACITY FOUND DURING THE FIRST AND SECOND CYCLES OF THE EXPERIMENTS

Experimental cycle	Total number of test subjects	Progressive group	Stable group	Regressive group
		as a per cent		
1	228	29	41	30
2	27	48	26	26
Difference in the percentages		19	15	4

experiments). This created favorable conditions for forming stable dynamic stereotypes, i. e., sensomotor skills marked by increased imperviousness to hindrances. It may be assumed that because of the formation of sensomotor automatisms, the total percentage of unreliable test subjects was reduced by 4%, while the progressive group showed the greatest increase (about 19%) and the percentage of test subjects falling into the stable group was reduced by 15%.

Thus, comparison of the experimental data once more confirms the conclusion that skill formation is one of the factors promoting an increase in the reliability of a person's work under conditions of stress. It is characteristic that along with an increase in the number of subjects in the progressive group, there is a drop in the percentage accounted for by the stable group (Table 6).

Everything that has been said indicates that formation of sensomotor control skills may serve as one of the ways of increasing the reliability of a person's work in a systems-technology complex. However, this method is inapplicable when dealing with unforeseen emergency situations, the solutions to which cannot be found by stereotyped means.

Moving on to a more detailed qualitative analysis of the psychic states of the test subjects and the features of their behavior at various stages of the experiment, we should first of all describe their activity during the training series of experiments.

At the beginning of the training period, emotional tension was /68
clearly visible in the case of the overwhelming majority of test subjects. It was manifested in their posture, movement of facial muscles, constraint, impulsiveness, and insufficient coordination of sensomotor actions. Their attention was directed above all toward prompt execution of motor coordination actions. Thinking aloud, the test subjects found out where and how it was necessary to move their hands or feet and they did their work at a retarded rate with a large number of erroneous actions. As they developed the sensomotor coordinations, their attention shifted more and more to the view finder. The test subjects became more and more adept at performing the individual operations, although the interconnection among these operations was still insufficient for developing precise interaction.

The test subjects subsequently developed an individual work style, and this was accompanied by a reduction in the number of errors and by increasingly prompt swtiching and distribution of attention. Their movements became increasingly smooth and coordinated. It was precisely at this stage of skill formation that significant individual differences in our test subjects' behavior and work capacity manifested themselves. Here fatigue inevitably had its effect. The test subjects began to complain of weariness, aches, and pains in their wrists, legs, lumbar regions, and other parts of their bodies. Fatigue had an especially strong effect on their vision; consequently, their concentration was not as good and the performance of voluntary movements was made more difficult.

In order to continue the training, the test subjects needed volitional efforts and the ability to mobilize themselves to overcome both subjective and objective difficulties. Here the

individual's volitional qualities came to the fore: his persistence /69
and tenacity in achieving the goals that had been posed.

Thus, formation of a dynamic stereotype is inseparably connected with the emotional-volitional sphere of the personality. It serves as a kind of touchstone of a person's emotional-volitional qualities.

In a person's work activity, emotional tension, which is a manifestation of the mobilization of activity, is always closely connected, and interacts, with volitional processes, which insure self-regulation and self-organization of work actions. However, as skills become automatic, the functioning of the dynamic stereotype gradually leads to a dying down of emotions and to a reduction in conscious monitoring and voluntary attention, as well as to a saving of volitional efforts and the nervous-psychic expenditures connected with them.

"...Formation of a motor operation or motor skill," A. N. Leontyev emphasizes, "begins, as is well known, with mastering it in the form of an action that is consciously performed. Then this action is made a part of a more complex integral action, in which it is 'given the finishing touches' and begins to be performed as if if were automatic." [27]

As a result of being performed many times under constant conditions of activity, actions are transformed and lose their conscious orientation, the method by which they are performed becomes automatic and they are turned into a skill. The objective relationships or external stereotype of the relevant conditions of its performance is fixed in a skill or operation.

Thus, not only awareness of the goal of a nonautomated action, but also concentration of attention of choosing methods for performing it and on using these methods are characteristic of this action. When the action has become sufficiently automatic, thanks to long practice or special exercises, the goal and conditions of performing it cease to be objects of attention and are only monitored

with the aid of consciousness. Very often the monitoring is done not in the actual process of performing the action, but indirectly, through assessment of the results of the action.

Psychological studies of the neurodynamics of brain processes during the formation of abilities and skills that have been done by Ye. I. Boiko [28] have shown that when a person performs exercises under conditions that repeat themselves in a stereotyped manner, /70 an ordered system or dynamic stereotype of conditioned reactions is created in the cerebral cortex. However, thanks to exercises performed many times, as automatic skills are formed, the regulating role of the second-signal connections is noticeably diminished. In the opinion of Ye. I. Boiko, the basic regularity in the formation of a person's sensomotor skills consists of a progressive shift from second-signal coordinations to first-signal coordinations.

The functioning of the skills is based primarily on first-signal dynamic stereotypes, which usually operate with minimum monitoring on the part of the second-signal system. Monitoring by this system of the performance of automatic actions is intensified only when the usual conditions of activity change. Thus, a person who has automatic work skills on a given machine tool can perform an ordinary assignment on it while simultaneously thinking about various other matters. However, as soon as there is any trouble with the machine tool that changes the working conditions, the worker tries to find out the causes of the trouble and consciously seeks ways to eliminate them.

Work abilities come to the fore under these conditions. These abilities are manifested in a worker's capacity under changing conditions to succeed in achieving a consciously posed goal of work activity that is new to him, by creatively applying unified means and methods of performing the work. As automatic components of abilities, skills continue to play an important role in the operator's activity, but one that is subordinate to abilities.

The elements of the structure of operator activity in which algorithmic methods and techniques of performing work actions that are implemented in a stereotyped manner are put into practice, become automatic through exercises in which the same goals are achieved many times. These elements begin to function as automatic actions, i. e., as operations.

Operations and the vocational skills inseparably connected with them constitute the basic content of operator activity under optimum working conditions. The important role of skills consists in the fact that, as S. L. Rubinshtein has correctly noted, they free conscious activity from the regulation of relatively elementary actions, and it can be directed toward the solution of more complex problems. At the same time, as vocational skills become automatic /71 and are strengthened, work activity is carried out without appreciable volitional efforts, since emotional tension disappears. As V. L. Marishchuk, K. K. Platonov and Ye. A. Pletnitsky have established, the tension that is caused by insufficient development of certain flying qualities disappears in the process of forming and strengthening the skills involved in piloting techniques, and this compensates for shortcomings with respect to such vocationally important flying qualities as distribution and switching of attention, coordination of movements, etc. However, this compensation does not insure the development and improvement of the personal qualities that determine the reliability and effectiveness of the performance of operator functions under extreme working conditions. Here general technical abilities come to the fore. These abilities represent a structural combination, formed in the process of the practical application of general technical knowledge and skills, of qualities that are important for every technical vocation and that assure them successful creative use of equipment in achieving work goals by means of the rational utilization of unified methods, techniques and means of performing the work. Success in mastering each general technical ability depends on the presence of knowledge, skills, and conditions that promote the inculcation of the specialist's vocationally important personal qualities, and on the level of automation. General technical abilities are a necessary component

of the operator's vocational mastery. They are universally applicable and consequently common to all types of operation work. Formation of general technical abilities involves the sensomotor, intellectual, motivational, moral, emotional-volitional, and other vocationally important spheres of the personality. When the proper methods of guidance are used, it promotes the comprehensive development and inculcation of the personal qualities that are used in a given type of work activity. What has been said gives us grounds for assuming that the formation of general technical knowledge, abilities and skills is an effective means for the psychological and practical training of the specialists who control modern equipment.

Our studies have shown that mastering abilities requires volitional efforts and concentrated attention and inevitably involves emotional experiences. Successfully overcoming the difficulties involved in achieving the goals that have been posed raises the pupil's self-esteem and evokes in him a sense of worth, satisfaction and confidence in his powers. Because of this, the process of the formation of work abilities inevitably involves the improvement of /72
the emotional-volitional sphere of the personality and also evokes in the individual a sense of mastery and a positive, responsible, and conscientious attitude toward work, which is inseparably connected with this sense of mastery. Inculcation of all these personal qualities is a necessary condition for increasing the reliability and effectiveness of the performance of operator functions under various working conditions.

5. On the Interconnection Between the Psychological and Physiological Indicators of Reliability

One of the chief aims of this work was to determine the degree of interconnection between the indicators of psychological functions and the indicators of vegetative functions that characterize the activity of test subjects under experimental conditions.

When one analyzes the data obtained from the process of sensomotor skill formation, one can easily see that during the initial stage of the training, the pulse rate of 26 test subjects increased by 8.4 beats per minute on the average. The maximum increase in the pulse rate, from 92 to 112 beats per minute, was observed in the case of test subject G. The smallest increase in the pulse rate was four beats per minute, which was observed in the case of 11 test subjects. In only one case was there a decrease in the pulse rate, from 100 to 96, i. e., a decrease of four beats per minute. The pulse rate of four test subjects remained constant throughout the skill formation experiment.

Summarization of the results of pulse rate measurements done immediately after the sensomotor skill was formed showed that under these conditions the pulse rate of 27 subjects decreased as compared to the initial stage of skill formation, by 5.9 beats per minute on the average. If one compares the average magnitudes of the pulse rate at the start of skill formation and after it, one may reach the following conclusion: In the initial stages of the formation of the dynamic stereotype, the pulse rate of the overwhelming majority of test subjects increased by an average of 8.4 beats per minute, by an average of 5.9 beats, and it decreased after the skill had become automatic. Thus, there was an average net increase of 2.5 beats per minute in the pulse rate at the end of the skill formation, as compared to the initial rate.

In the extreme series of experiments, changes in the functioning of the cardiovascular system were even more sharply manifested. Thus, performance of assignments on the emocoordinometer under conditions in which the stress factors were applied was accompanied by a considerable increase in the pulse rate of all the test subjects without exception. The average increase was 16 beats per minute, the greatest increase was 36 beats (test subject F. V.) and the smallest increase was 4 beats (test subject Kh. D.). When the work under extreme conditions had been completed, the pulse rate of the overwhelming majority of subjects dropped, from 87.75 to 82.24 beats per minute on the average, i. e. a decrease of 5.5 beats per minute.

/73

However, in this case as well the pulse rate remained higher than before the experiments, when the average magnitude was equal to 71.42 beats per minute, but this time the net increase was equal to about 11 beats per minute. Along with this, it should be noted that after the experiments in the case of three test subjects there was a below average drop in the pulse rate — a decrease of two to five beats per minute.

By comparing the data presented above, one may draw the conclusion that the changes in the pulse rate during the formation and the functioning of the skill under conditions of stress are not entirely similar. There is a similarity with respect to the trend toward an increase in the pulse rate. However, in the first case this trend was characteristic of 26 test subjects (84%), while no increase was observed in the pulse rate of the other 5 test subjects. But under the extreme conditions a considerable increase in the pulse rate of all the subjects without exception was observed. This increase averaged 16 beats per minute, whereas during the skill-formation series of experiments the average increase was 5.9 beats per minute. When one compares these magnitudes, one can easily see that the increase in the pulse rate under extreme conditions was approximately 2.8 times greater than the increase in the pulse rate observed during the development of the dynamic stereotype. What has been said indicates that there are substantial differences in the emotional tension of our test subjects under different working condtions. It should be emphasized that in the current literature dealing with this question there are different points of view. Some authors (Kh. Eliash and K. Lager, I. Lazarus, A. Krzhizhanovsky, M. Frankenkhoizer, and others) have established through experimental studies that the pulse rate and blood pressure increase under conditions of stress and that they even drop in the case of some test subjects. Others (R. Luft, Scott, G. N. Shishkin) believe that there is no substantial change in either the pulse rate or blood pressure under conditions of stress and that they even drop in the case of some test subjects. Still others (I. Lazarus, K. Bronner, and others), [29] as a result of experiments, have reached the conclusion that reactions to stress /74

are very specific. Because of the features of their constitution, some test subjects may constantly react with an increase in blood pressure without showing an increase in their pulse rate, while in the case of others the pulse rate will increase and blood pressure will drop. I. Lazarus has called this specificity of reactions the individual reactive stereotype. He believes that one must know the most sensitive and reactive indicator for any given individual. If the experimenter does not know this, he may reach erroneous conclusions concerning the intensity of the reaction to stress. To a certain extent, the results of our experiments confirm the viewpoint of Kh. Eliash, A. Krzhizhanovskiy, and others.

The conclusions set forth above tally well with the data from a comparative analysis of the frequency of heart contractions that were recorded during the training of cosmonauts in an altitude chamber (AC) and under actual conditions of space flight.

In studies in which cosmonaut N. A. Leonov took part, his pulse rate was recorded as he performed identical operations during training on the Earth (in the AC) under optimum conditions, and under the extreme working conditions of space flight.

N. A. Lukyanov and M. V. Frolov [30] have established that a minute before launch the magnitude of the pulse rate exceeds the corresponding value in the AC by 20 $\rightleftarrows$ 30 beats per minute, which, in their opimion, is due to the great emotional tension that results from the prelaunch state. The greatest increase in the pulse rate, up to 130 — 150 beats per minute, occurred during the cosmonaut's "free floating" in space. When this operation was performed in the AC, the pulse rate was normal, 70 — 72 beats per minute. The experimental data that have been cited provide grounds for believing that when the cosmonaut performed training exercises in the AC, the change in his pulse rate was due primarily to physical loads, but when he functioned under the actual conditions of space flight, the effect of emotional tension was predominant.

Thus, both physical and emotional tension cause an increase in the pulse rate, Therefore, as the researchers who have been cited correctly assert, it is not yet possible to distinguish the cause and nature of tension on the basis of data concerning vegetative reactions. These conclusions call into question the possibility of /75 using the frequency of heart contractions as a criterion to determine the reliability of the performance of operator functions in complicated and emergency situations.

The correctness of this statement is proved by generally known facts that indicate that the level of reliability and effectiveness of the operator's work is often weakly correlated with the indicators of vegetative functions. For example, though he had an extraordinarily high pulse rate of 130 beats per minute, cosmonaut Leonov effectively performed the functions assigned to him. At the same time, it has been observed that other fliers have suffered a total loss of work capacity even though their pulse rate was close to normal.

Ascertaining the opportunities for diagnosing the level of a person's work capacity on the basis of his physiological parameters is of definite practical and theoretical significance.

The point is that recently researchers (R. S. Dodashev, Ye. N. Murashev, A. N. Lukyanov, M. V. Frolov, and others) have been trying to prove that it is necessary to use methods of diagnosing an operator's work capacity and of determining his functional states that are based on quantitative treatment of changes in his electroencephalogram and the indicators of changes in his vegetative functions. It is well known that in response to the effect of difficult and stressful situations, very substantial changes occur in the human organism in the activity of the cardiovascular, visceral, vegetative, humoral, endocrine, central nervous, and other systems.

Nevertheless, proceeding from the results of many years of research on emotional states, we must emphasize that the development of these states is inevitably governed and regulated by means of feelings and volitional processes that are consciously carried out.

Viewing emotions, feeling, and will as a single psychic process of self-mobilization, self-organization, and self-regulation of psychic activity, naturally we cannot find out its content and determine the quality, reliability and effectiveness of a person's work by relying exclusively on changes in his pulse rate, on the amount of corticosteroids, on the percentage of blood sugar, etc. All of these indicators can and should be taken into account in any psychological experiment. However, the main role in such experiments must be played by psychological criteria and by the methods of integral structural study of man as a working entity.

We have found proof that the personal approach to studying the phenomena that interests us is productive in the course of further analysis of the experimental data that we have obtained, /76 which reveal the important and decisive role of volitional regulation during emotional states and of the reliability of a person's work under different working conditions.

For example, at the beginning of the training, test subject F. L.'s behavior was unsure, cautious, and tense, his movements were constrained and slowed down and he directed all his efforts toward moving the view finder in the assigned target area as accurately as possible. He worked silently and with concentration and strove to master the actions involved in performing the most difficult part of the assignment. He reached a high control coefficient (0.81) relatively quickly, at the $20^{\underline{th}}$ exercise. Subsequently, as the skill was formed, the test subject's tension diminished, he coordinated his movements better and he began to control the view finder freely and easily. At the $26^{\underline{th}}$ exercise he began to complain of general fatigue. However, he worked with the same earnest effort and increase his high work indicators. At the end of the training he was working quickly and accurately, with an insignificant number of errors. This test subject performed the sensomotor actions with varying success, but his exercise curve was marked by a steady trend toward improvement. At the end of the training he had reached a plateau, which indicates that he had developed a stable automatic skill.

At the beginning of the extreme series of experiments F. L.'s behavior was composed and organized, and he tried to work as accurately and as well as possible. However, when he was subjected to the ESS, the coordination of his movements was disrupted. When the experimenter asked him what hindered him the most in his work, he replied: "The noise did not have much of an effect; you can ignore it and you can beat the shield, but the current was what hindered me most." These statements were confirmed by the observations of this test subject, who, when subjected to the ESS, grimaced in pain, began to shake, and waved the hand to which the current was being applied. He made every effort to avoid being subjected to the ESS. At the $30^{\underline{th}}$ exercise he began to complain of weariness. However, on the advice of the experimenter he changed his position and concentrated on performing the work, which he completed with a high indicator ($r = 0.87$).

A characteristic trait of this test subject was a high level of self-regulation of behavior, whose effectiveness increased in response to the growth of the difficulties standing in the way of achieving the goal.

Comparison of the psychological and physiological characterizations makes it possible to draw the following conclusions, with respect to the data concerning this test subject: During skill formation his pulse rate increased by 12 beats per minute, while under extreme conditions the increase was equal to 36 beats, the average being 16 beats. This indicator was the highest among all the participants in the experiment. The adrenaline tests showed a small decrease in the amount of adrenaline in the urine under extreme working conditions. There was an insignificant increase in noradrenaline, on the order of 1.0 — 1.5 mg/min. Under extreme conditions the amount of blood sugar rose by 32%, which exceeds considerably the average magnitude for the entire group. There was no substantial change in arterial systolic pressure under the different working conditions. Thus, the sharpest changes in this subject's vegetative functions occurred in his pulse rate and in the amount of blood sugar.

/77

Another member of the progressive group (S. A.) achieved a record high in reliability, r = 0.29, for work under extreme working conditions. In his case there was a somewhat different picture with respect to changes in physiological functions. Thus, his pulse rate increased by 12 beats per minute, which was considerably lower than the average of 16 beats per minute. No change at all was observed in arterial pressure. The amount of adrenaline dropped from 11.45 to 6.81 mg/min., i. e., almost down to 59%oof the original level. The amount of noradrenaline fell from 36.00 to 23.48, down to 65% of the original level. In these experiments there was also an insignificant increase in blood sugar (19%).

When one compares the parameters presented above, one can easily see that in the case of two of our test subjects who had high reliability indicators, the characterizations of the trends in the change in physiological parameters according to all the basic indicators are obviously different, although in both cases there is a trend toward an increase in these parameters.

As a rule, the test subjects became fatigued as they performed the assignments, which was indicated by the objective indicators, by the data from verbal statements, and by the observations. This fact created additional difficulties, and overcoming them required considerable volitional efforts, internal tension, stamina, and mobilization of strength.

The struggle against fatigue was clearly manifested in the case of test subject I. G., a member of the first group. After he had performed 25 exercises, his work began to deteriorate, he began to make mistakes, he complained of fatigue and pain in his back and his /78
arms and legs began to shake. "I must master myself," he said, "I must complete this work and manifest my will." Under the influence of this order from himself, he completed the work by making great nervous-physic efforts. I. G. said in his statement that he thought only about not making errors and wanted to do the best possible job in performing the assignment, and that he had no other thoughts.

The test subjects in this group were very active psychologically, and this activity was aimed at supressing weariness and the feeling of fear caused by the stress factors. They showed patience, endurance, persistence, and a capacity for lengthy volitional efforts.

The data obtained indicates that these test subjects belong to the progressive category of people who, when properly motivated, are capable of significantly increasing the reliability and effectiveness of their work. In the majority of cases, their behavior is marked by heightened emotional tonus and economical expenditure of physical and nervous-physic strength. For the most part, they work creatively, easily and without constraint and take pleasure in their work. Naturally, under the actual conditions of life and work all these personal qualities are manifested in different ways by different individuals.

The psychological characterizations that have been presented for the test subjects that we placed in the progressive group clearly show the activating and mobilizing effect of the stress factors, which act as subdominants that promote the improvement of self-regulation and organization and an increase in the productivity of the basic work activity.

We obtained equally interesting data from an examination of the changes in the psychophysiological activity of the test subjects whose reliability indicators were stable under the different working conditions. There were seven subjects in this group.

Summarization of the data from the record sheets has enabled us to characterize in the following manner the features of the behavior of the test subjects in this group. In contrast to the members of the first group, the overwhelming majority of the members of this group showed a periodic variation in their success in performing the sesomotor functions under stressful working conditions, as compared to their average work indicators during the training series of experiments. A period of improvement was followed by a period of decline in the indicators. Thus, the average tracking

coefficients for optimum and extreme working conditions were usually equal; therefore, the difference between them was usually close to 0.

The psychic states of these test subjects were marked by rhythmical rises and falls in activity, which were the result of /79 their high mobility and insufficient equilibrium. Rhythmical variations in emotional tension, periodic variations in concentration of attention, rapid switching of attention, impulsiveness with respect to volitional efforts and the actions connected with them, and a persistent desire to achieve the goal are characteristic attributes of these test subjects. Test subject Z. P. is a typical member of this group.

At the start of skill formation, Z. P. worked without confidence and was very tense; his face was concentrated, his torso was leaning forward and he clenched his fists convulsively. His movements were impulsive and chaotic and he tried to work more slowly, but from time to time he involuntarily speeded up and slowed down his work pace. He "marked time" in one place for a long time, and his movements were poorly coordinated. At the end he was working more confidently and was less tense, but his impulsiveness and variations in attention, as well as the periodic rises and falls in his work effectiveness, remained. As a result, his reliability coefficient $R \approx 0$. Here we have a rather rare case of precise coincidence of the magnitudes of the control coefficients obtained under instructional-training and extreme working conditions. Judging by the entries in the record sheets, this stability of reliability [illegible] indicators was achieved at the cost of extraordinarily great nervous-physic expenditures and a high level of emotional tension, which should inevitably be reflected in changes in vegetative and visceral functions. When one compares pulse rates, one can easily see that during the training experiment, the pulse rate rose by four beats per minute, whereas under extreme conditions it rose by eight beats, which is half the average magnitude of this indicator (16). No substantial changes in arterial pressure were observed either: The systolic pressure did not change, while the diastolic

pressure rose by five units. The amount of adrenaline remained constant, though the noradrenaline test showed insignificant increases of six mg/min. during the first series of experiments and nine mg/min. during the second. The amount of blood sugar remained constant, since the changes did not exceed 1%.

Moving on to an examination of the results characterizing the activity of the participants in the experiment who had lower work indicators under conditions of stress, we should note first of all the extraordinarily heterogeneous, variegated, and sometimes even contradictory nature of the characterizations of their behavior. In our view, this is no accident, since the effectiveness of activity may be affected by an extraordinarily great number of factors, and /80 it is not always possible to ascertain the character of their interconnections and interaction. Nevertheless, analysis of the descriptions of behavior, the verbal statements and the objective data in the record sheets has enabled us first of all to single out a group of test subjects whose behavior was more or less clearly affected by sluggishness, constraint, and inhibition due to the effect of stress factors. A characteristic feature of these test subjects was confusion and an inability to mobilize themselves to overcome difficulties. Whereas under ordinary conditions they were more or less successful in developing the sensomotor skill, there were chronic errors, lapses, failures, and work disruptions during the functioning of the skill under extreme conditions.

Thus, for example, test subject G. P. said that he was most afraid of the shield, and in fact the observations showed that G. P. worked slowly. At the moment when the shield caught up with him, he began to get very agitated, made many errors, became flustered, and, instead of moving the view finder to the right, moved it in the opposite direction. Under extreme working conditions all these characteristics of his individual work style came out even more clearly. G. P. was very tense while working, his lips were pressed close together, his muscles were at maximum tension, he squeezed the control lever convulsively and sweat appeared on his forehead.

His work was unstable and his indicators fluctuated. He said that he was unable to concentrate for a long time and therefore had to relax periodically; he complained of weariness and asked that he be given a break to rest. At the end of the work he was not making volitional efforts; therefore, he did not always manage to beat the shield, and when the speed was increased the number of errors rose considerably. He said that the shield had the greatest effect on him at the beginning of the experiment, but at the end he was hindered most by the noise; therefore, he was very tired, he had a headache and his legs were shaking.

Among the members of this group there were also subjects in whom prolonged difficulties and failures produced a chronic state of alarm and lack of self-confidence. Usually they tried to avoid being subjected to the stress factors under the most varied pretexts and refused to continue the difficult work. Having failed, these test subjects tried to place the blame on the apparatus that did not work properly, insufficient instruction by the experimenter, the obstructive effect of the noise, a light that was too bright, and other circumstances that had nothing to do with them.

Thus, the feelings involved in a state of fear and alarm played the leading role in the behavior of these subjects under extreme working conditions. /81

It should also be noted that we did not encounter typical examples of the aggressive-uncontrolled type of behavior among our test subjects. At the same time, occasionally some of the participants in the experiments whose reliability indicators dropped showed certain traits of aggression, manifested in outbursts of rage, in a brief loss of control over themselves and in entering into an affective state.

In contrast to the experiments in which the candidates for admission to air academies took part, in these experiments we did not observe any complete disruptions of activity. In all probability, there were no examples of the aggressive-uncontrolled type of

behavior in this case because all of our test subjects were upperclassmen at higher educational institutions and had been subjected to natural selection both during the admission process and while attending these institutes.

The data cited clearly indicates that recording changes in the activity of the cardiovascular and sympathico-adrnal systems still does not enable us to judge the level of a person's work capacity and his state. Obviously, the most reliable assessments can be obtained on the basis of psychological parameters obtained by means of special research methods.

The correctness of this conclusion is also confirmed by the results of correlation analysis of the experimental data.

Below we present a summary table of the results of correlation analysis of the experimental data, which shows the correlation coefficients between the magnitude of R., which is the overall indicator of the reliability of the performance by the test subjects of the sensomotor functions, and the physiological parameters characterizing changes in the activity of the cardiovascular, endocrine, and hematogenous systems (Table 7).

When one examines the data presented in the table, one can /82
easily see that the only positive correlation with R is between R and adrenaline, and it is very insignificant (0.08). The correlation coefficients reflecting the nature of the interconnection between the reliability indicator and the change in the amount of noadrenaline (-0.03), systolic pressure (-0.07), diastolic pressure (-0.08), and the amount of blood sugar (-0.08) are also close to zero.

Thus, we have grounds for asserting that the indicators listed above do not have a substantial effect on the effectiveness and reliability of the performance of sensomotor functions. As for the pulse rate and the amount of leukocytes and erythrocytes in the blood of a person who performs these functions under extreme working

TABLE 7

SUMMARY TABLE OF THE RESULTS OF CORRELATION ANALYSIS OF THE EXPERIMENTS

Physiological factor	Correlation coefficient	Physiological factor	Correlation coefficinet
Adrenaline in the urine	+0.08	Blood sugar	-0.08
Noradrenaline in the urine	-0.03	Erythrocytes in the blood	-0.2
Systolic pressure	-0.07	Leucocytes in the blood	-0.26
Diastolic pressure	-0.08	Pulse	-0.26

conditions, there is a negative correlation of -0.02 to -0.026, which indicates the existence of a small negative connection between these indicators and reliability and level of work capacity.

Everything that has been said above indicates the promise of experimental psychological systems-structural study of the operator's work activity, aimed at creating a psychological conception of emotional-volitional actions and, on this basis, developing new methodological approaches to solving the problems involved in further increasing the effectiveness and reliability of the work of the specialists who control modern equipment.

REFERENCES

1. Berg, A.I. Cybernetics in the Service of Communism. In the Collection: Kibernetiku na sluzhbu kommunizmu (Cybernetics in the Service of Communism). Gosenergoizdat, Moscow, 1961, p. 17.

2. Lomov, B.F. Chelovek i tekhnika (Man and Technology). Sovetskoye radio, Moscow, 1966.

3. Derevyanko, Ye.A. Vzaimootnosheniya mezhdu nekotorymi fiziologicheskimi i psikhologicheskimi faktorami pri razvitii utomlenia v protsesse trudovoy deyatel'nosti (The Interrelationships Among Certain Physiological and Psychological Factors in the Development of Fatigue in the Process of Work Activity). Tezisy dokladov na I sezde Obshchestva psikhologov USSR (Theses of the Reports at the First Congress of the USSR Psychologists' Society). No. 1, Moscow, 1959.

4. Lomov, B.F. Accuracy in the Operator's Work. Inzhenernaya psikhologiya (Engineering Psychology). Moscow, 1964.

5. Linkoln, R.S. Human Factor in the Attainment of Reliability. The Trans on Reland Quatcont. April, 1960.

6. Nebylitsin, V.D. Reliability of the Operator's Work in a Complex Control System. Inzhenernaya psikhologiya (Engineering Psychology). MGU Press, 1964.

7. Leont'yev, A.N. and D.Yu. Panov. Psikhologiya cheloveka i tekhnicheskiy progress (Human Psychology and Technical Progress). Moscow, 1962, p. 48.

8. Inzhenernaya psikhologiya (Engineering Psychology). MGU Press, 1964, p. 125.

9. Oshanin, D.A. Semanticheskaya i pragmaticheskaya funktsiya signalov (The Semantic and Pragmatic Function of Signals). Tezisy dokladov na II sezde Obshchestva psikhologiv. (Theses of the Reports at the Second Congress of the Psychologists' Society). No. III, Moscow, 1963, p. 104.

10. Lomov, B.F. and S.N. Leviyeva. The Study of Operator Tracking Activity. Voprosy psikhologii, 1965, p. 1.

11. Zavalishina, D.N. and V.N. Pushkin. On the Mechanisms of Operative Thinking. Voprosy psikhologii, 1964, p. 3.

12. Pushkin, V.N. Operativnoye myshleniye v bol'shikh sistemakh (Operative Thinking in Large Systems). Energiya Press, Moscow, 1965.

13. Teplov, B.M. Problemy individual'nykh razlichiy (Problems of Individual Differences). Moscow, 1961.

14. Chebyshevа, V.V. Nekotoriyye osobennosti myslitel'nykh zadach v trude operatora (Certain Features of Cognitive Tasks in the Operator's Work). Tezisy dokladov na II sezde obshchestva psikhologov (Theses of the Reports at the Second Congress of the Psychologists' Society). No. III. Moscow, 1963, Certain Questions of the Psychology of Production Training. Voprosy psikhologii, 1959, p. 2.

15. Lomov, B.F. Chelovek i tekhnika. (Man and Technology.) LGU Press, 1963.

16. Levandovskiy, N.G. Struktura psikhicheskoy regulyatsii deystviy operatora pri upravlenii mashinami i priborami (The Structure of the Psychic Regulation of Operator Actions in Controlling Machines and Instruments) Candidate's Dissertation. LGU Press, 1961.

17. Dymerskiy, V.Ya. Psikhologicheskiy analiz raboty naladchikov i zadachi obucheniya naladke (Psychological Analysis of the Work of Servicement and of the Task of Training Servicemen.) Tezisy dokladov na soveshchanii obshchestva psikhologov (Theses of the Reports at a Conference of the Psychologists' Society) Moscow, 1961.

18. Zavalishina, D.N. and V.N. Pushkin. O mekhanizmakh operativnogo myshleniya. (On the Mechanisms of Operative Thinking.)

19. Pushkin, V.N. Operativnoye myshleniye v bol'shikh sistemakh (Operative Thinking in Large Systems).

20. Mistyuk, V.V. Psychological Characteristics of Developing Production skills in Higher Schools. Naukovi zapiski NDI psikhologii, XV.

21. Levandovskiy, N.G. Struktura psikhicheskoy regulyatsii deystviy operatora pri upravlenii mashinami i priborami (The Structure of the Psychic Regulation of Operator Actions in Controlling Machines and Instruments). Candidate's Dissertation.

22. Mileryan, Ye.A. Psychological Characteristics of Transferring Production Skills to Higher Schools. Naukovi zapiski NDI p psikhologii, XV. Radyans'ka Shkola Press, Kiev, 1961.

23. See the article by these authors, "On Increasing the Reliability of the Work of Railroad Engineers," in this collection.

24. Platonov, K.K. Psikhologiya letnovo truda (The Psychology of Work in an Airplane). Moscow, 1960, pp. 130-133.

25. Boyko, Ye.I. Toward Formulating the Problem of Abilities and Skills. Sovetskaya pedagogika, 1955, p. 1.

26. Jones, H.J. Should Colonel Henn Try Again? New Scientist, No. 273, 1962, p. 13.

27. Leont'yev, A.N. and D.Yu. Panov. Human Psychology and Technical Progress. In the Collection: Filosofskiye voprosy fiziologii vysshey nervnoy deyatel'nosti i psikhologii (Philosophical Questions of the Physiology of Higher Nervous Activity and of Psychology). USSR Academy of Sciences Pres s, Moscow, 1963, p. 420.

28. Boyko, Ye.I. Toward Formulating the Problem of Abilities and Skills. Sovetskaya pedagogika, 1955, p. 1.

29. Lazarus, I. The Theory of Stress and Psychophysiological Research. In: Emotsional'ny stress (Emotional Stress). Moscow, 1969.

30. Luk'yanov, N.A. and M.V. Frolov. Signaly sostoyania cheloveka-operatora (Signals of the State of the Operator). Nauka Press, Moscow, 1969, p. 203.

N75 17949

DISCUSSION AND THEORETICAL SUMMARIZATION OF THE EXPERIMENTAL DATA

Ye.A. Mileryan

Among the factors that cause substantial changes in the reliability indicators of an operator's work, stressful situations play a central role. /83

The problem of the emotional stability and, consequently, of the reliability of an operator's work in the system "man — automated device" is one of the most pressing but at the same time poorly studied problems of present-day labor psychology. This problem has not been adequately studied, first, because of the extraordinary complexity of emotions and their close intertwining with other psychic processes and, second, because of the lack of sufficiently reliable methods for the objective study of emotional states.

In setting about an analysis and theoretical summarization of the experimental data, naturally we should first of all summarize the data available in the literature concerning the nature of will and the regularities governing the appearance of emotions and establish their reciprocal connection with other psychic phenomena, in order to bring to light the interconnection among the emotional-volitional components of man's work activity.

In modern psychological literature there are a number of theories that claim to reveal the nature of emotions. We find the earliest theories in the works of James, who advanced the following hypothesis in his The Principles of Psychology, which was published in 1890: "The natural course of our thoughts with respect to these simple emotions (i.e. grief, fear, rage, love) is that our subjective perception of a certain fact stimulates a subjective feeling, /84 called an emotion, and this latter state of the spirit causes bodily changes. My theory, on the other hand, is that bodily changes directly follow the perception of the factor stimulating the organism and that our feeling these very changes, insofar as they occur, is

... any bodily change, whether it be clear or indistinct, is felt right away, as soon as it occurs."

Thus, James, and Lange after him, assert that emotion is the result of feeling bodily changes caused by an emotion-provoking stimulus acting on the organism.

The theoretical suppositions of James and Lange were justly criticized by Sherington, Kennon, Mons, Brigton and other authors, who showed on the basis of data from specially organized experimental psychological studies that destroying the nerve paths that connect the brain with the internal organs and cutting the nerves by means of which visceral changes are perceived do not lead to the disappearance of such emotions as anger, fear, joy, disgust, rage, etc.

Through summarization of the results of research on the physiological mechanisms of the emotional states of animals, as well as on the basis of study of data from clinical neurology, the so-called thalamic theory of emotions was formulated in the works of Kennon, Head and Beard; according to this theory, the specific quality of emotions is added to simple feeling when thalamic processes are stimulated. As if by means of reverse circular connections, these processes in turn increase the intensity of the cortical processes caused by the given stimulus.

The theoretical propositions of Kennon were sharply criticized by such researchers as Newman, Pervinson, Lashley, Arnold and others. In his book A Stimulation Theory of Emotions, Arnold attempted to define emotion as a stimulation phenomenon that is transmitted along special cortical-hypothalamic paths that are in contact with the various hypothalamic effector systems. We find a definition of emotions that is more adequate from our point of view in the works of Liper, who believed that a person's emotional behavior is based on the processes that organize and mobilize his forces.

Generalization of data obtained from studying the electrical

activity of human and animal brains enabled D.B. Lindsley to formulate the activation theory of emotions, according to which emotional /85
states result from the activation of the nervous mechanisms of the lower levels of the spinal column of the brain. The afferent impulses then spread in the hypothalamus and the thalamus, activating the centers located in the rostral part of the mesencephalon and at the base of the diencephalon. Reaching the cortex through a diffuse projection system, they activate considerable sections of the cortex, and this results in the appearance of emotional reactions that are often unclear and poorly differentiated.

Thus, according to Lindsley emotions are the result of sequential activation of higher and higher levels of the central nervous system.

R. Giss [1] studied the correlations between behavior and brain activity and came to the following conclusion: "Emotions regulate the level of work capacity of the cerebral cortex through the rising tonic effect of the reticular formation. In addition, they help to mobilize the experience that is stored in the conditioned-reflex connections of the cortex. In this regard, the sympathetic and parasympathetic sections of the vegetative nervous system have the effect of intensifying the activity of the cardiovascular, endocrine and respiratory systems, and this is accompanied by an increase in the sensitivity of the analyzers and in the strength, speed and accuracy of movements."

The Soviet scientist P. Simonov has recently advanced the so-called information theory of emotions. He asserts that an emotion represents "a physiological mechanism that compensates for a shortage of the information necessary to achieve goals (to satisfy needs)" [2].

First of all, the definition of emotions cited above indicates that psychological concepts have been incorrectly replaced by physiological concepts, and second, we strongly object to the interpretation of emotions as a mechanism that compensates for a shortage of

the information necessary to achieve goals, since emotions may appear when there is a surplus of such information. For example, we are familiar with I.P. Pavlov's thesis that emotions appear during the maintenance and breakup of dynamic stereotypes. In this /86 case an animal receives information that is quite sufficient to maintain or change a stereotype. However, emotions appear as a result of great nervous efforts, the breakup of the systems of connections established in the stereotype and the formation of new ones. It is obvious that from the psychological point of view an emotional state is characterized above all by a definite reflex mobilization of internal forces, which is a necessary condition for actively overcoming the obstacles and resolving the contradictions that stand in the way of satisfying vitally important needs.

When we examine the theoretical views set forth above, we notice the fact that the authors of the various theories have attempted to find the physiological mechanisms of emotions without thereby bringing to light the psychological nature of emotions and without ascertaining their role and significance in man's life and work.

Along with L.A. Vygotsky, we should admit that at the present time we still do not have any satisfactory psychological theories of emotions. Therefore, in order to resolve the questions involved in the role of emotions in the operator's work, we should formulate a more acceptable theoretical conception by summarizing the data available in the psychological literature.

In this connection, we must first of all endorse the theoretical propositions advanced in the works of Giss, Liper, Tib, Duffy and Webbs, who view emotional behavior as a process that organizes and mobilizes the forces of the personality. Developing these propositions further, we have defined an emotion as an involuntary mobilization of the organism's "essential" internal forces that is aimed at satisfying its vitally important needs and is organized in a certain manner.

According to the accepted thesis, passion is an essential

human force that is vigorously striving for its object.

In this apt characterization of emotional states, they are interpreted as a vivid manifestation of a person's "essential forces," which he mobilizes and directs toward the achievement of a definite goal. What has been said makes it possible to view an emotion as a conditioned-reflex mobilization and activation of the organism's essential forces, which play an extraordinarily important role in the formation and reorganization of the systems of conditioned-reflex connections.

In their works, I.P. Pavlov and his followers repeatedly emphasized the fact that emotions naturally appear as a result of the /87
development and reorganization of dynamic stereotypes. At the same time, the existence of emotional states is neither an epiphenomenon nor a working product of this process, but rather a necessary and decisive condition for any creative brain activity.

In a person's creative work activity, along with the emotional tension of the organs that are used to do the work, there is always his will, which is expedient, aimed at regulating and controlling work actions and manifested in attention.

In light of present-day ideas, attention is a form of organizing psychic activity that is manifested in its directed and concentrated nature and its relative stability. A certain interaction of the basic nervous processes of the brain in the form of a dominant or focus of optimum excitability serves as the physiological mechanism of this organization. A dominant appears during the reflection by a person or an animal of the variations and changes in his environment. It represents a creative area of the large hemispheres of the brain in which their analytic-synthetic activity, resulting in the formation of new systems of connections and in the reorganization of existing systems, is carried out most successfully.

Thus, attention acts as a basic form of organizing activity that ensures the improvement of experience and the acquisition of new

experience; this organization makes for the integrity, selectivity, directed nature, stability and self-regulation of psychic actualizing need.

The process of actively and creatively resolving the contradictions, overcoming the difficulties and removing the obstacles standing in the way of achieving a work goal that a person has posed necessarily includes the mobilization of his essential forces and capabilities, on the basis of which a definite organization appears and behavior is expediently regulated.

Appearing with the aid of emotions and developing thanks to them, attention, feelings and will serve at the same time as a basic means of organizing and consciously regulating human behavior. In order to prove this thesis, we should examine the interconnection among the functions of self-mobilization, self-organization and self-control during the development of higher nervous activity.

Donald B. Lindsley, the author of the so-called activation theory of emotions, has correctly pointed out that manifestations of emotions are always closely intertwined with other psychic processes. This is proved even by the fact that an electroencephalogram recorded at times of emotion constitutes an expression of an activation complex "that characterizes at the same time emotional awakening and a state of attention and timidity" [3-4]. Adrian, Jasper, Andrews and other researchers reached similar conclusions at one time. /88

The studies that we have done concerning the electrical activity of the human brain during attention to sonic stimuli have also shown that during emotional states brought about by musical works, the changes in the electrical activity of the brain were of the same nature as those occurring during involuntary concentration of attention on sonic stimuli [5].

The inseparable connection between attention and emotions is clearly manifested during observations of a person who is in an emotional state of fear, anger, joy, etc, which are characterized,

as K.D. Ushinsky wrote, "by the focusing of attention on the object of fear." [6]

The appearance of emotions is based on the actualization of organic needs, in which the contradictions between the organism and the environment find their expression. Emotional states constitute a "stimulating regulation" (S.L. Rubinshtein) of the organism's emotional behavior that is aimed at overcoming these contradictions. The orientative reflex is a necessary component of this behavior.

Research done by J. Delgado concerning emotional states caused by direct stimulation of a monkey's aggression centers by means of an electric current has shown that the animal attacks only those that he did not like before being subjected to the stimulus. Thus, it was proved that the emotional behavior of animals is directed by connections imprinted in the higher areas of the brain, connections that serve to regulate the organism's emotional behavior on the basis of past experience. Thus, J. Delgado's experiments, on the one hand, confirm I.P. Pavlov's suppositions to the effect that emotions play a stimulating, tonic role in the brain's activity: "The chief impulse for the activity of the cortex," I.P. Pavlov /89
wrote, "comes from the subcortex. If these emotions are eliminated, then the cortex is deprived of the chief source of its strength" [7]. At the same time, on the other hand, organizing and controlling emotional behavior depends entirely on the functions of the higher areas of the brain.

In man, emotions are always manifested in combination with volitional processes. Obviously, we should express our agreement with S.L. Rubinshtein's idea concerning the need to view emotions, feelings and will as a single psychic process. That is why study of the regularities governing work behavior should be based on consideration of the inseparable connection among the emotional-feeling, volitional and intellectual spheres of the human personality. From this, it becomes clear why any emotional behavior must include acts of both involuntary and voluntary attention.

Scientific analysis of the most diverse manifestations of the

emotional sphere of the personality enabled S.L. Rubinshtein to distinguish the following basic levels of this sphere: 1) The level of organic affective-emotional sensitivity; 2) the level of distinctness of feelings; and finally, 3) the level of summarized feelings expressed in the attitudinal posture of the personality.

The classification of manifestations of the emotional sphere of the personality that has been presented is in very close accord with I.P. Pavlov's doctrine concerning the three basic stages or genetic levels of the development of higher nervous activity. In this regard, I.P. Pavlov wrote that the entire totality of higher nervous activity may be represented in the following manner: "In the higher animals, up to and including man, the first level for the organism's complex relationships with the environment is the subcortex closest to the hemispheres, with its extremely complex unconditioned reflexes (our terminology), instincts, drives, affects and emotions (diverse ordinary terminology). These reflexes are engendered by a relatively large number of unconditioned, i.e., functioning from birth, external agents. Hence the limited orientation in the environment" [8]. Thus, I.P. Pavlov sees the first level of the organism's complex relationships with the environment as linked with the function of the mechanisms in the nearest subcortex. Instinctive emotional reactions play the leading role at the unconditioned-reflex level of reflection.

Numerous studies of the physiological mechanisms of emotions /90
that have been done in recent years by both foreign scientists and scientists in our country have made it possible to establish that the subcortical hypothalamic structures of the brain play the main role in organizing and regulating the emotion-provoking states of animals and humans.

The activity of these nervous formations involves satisfying the organism's biological needs and finds its expression in a whole series of inborn unconditioned-reflex forms of activity that is aimed at satisfying organic needs for food, air, self-preservation, continuation of the species, etc. Actualization of these needs leads to the formation of dominants in the corresponding subcortical

centers, which in turn causes a certain set of changes in the organism's activity, changes aimed at activating and mobilizing its internal resources. Therefore, during emotional states there are changes in the rate of breathing, blood pressure, heart rhythm and skin resistance, there is an intensification of the activity of the internal-secretion glands, etc. Along with this, each emotion is accompanied by a certain set of involuntary expressive movements, which can also play an important role in satisfying the need actualized at a given moment.

In the process of repeated satisfaction of organic needs, definite systems of conditioned-reflex connections are strengthened and formed on the basis of emotions.

Thus, the emotional tension that is accompanied by the mobilization of analyzers and internal organs acts as the decisive factor promoting the formation of new connections and, consequently, enriching the organism with new experience.

An inevitable component of emotional states is the unconditioned-orientative reflex, which is a specific form of organizing reflective activity at the first subcortical level and of the relationship between the organism and its environment.

Assuming that reflective activity at this first level has its own inherent organization, we may understand it as the primary and most primitive form of attention, which should be called involuntary unconditioned-reflex attention.

This most elementary form of organizing the reflective activity of living creatures finds its expression in certain kinds of /91
unconditioned reflexes, which I.P. Pavlov calls orientative-research reflexes. These reflexes have great vital importance for the organism. Any sufficiently strong stimulus that acts on a creature first produces a reflex posture of the receptors that corresponds to it, during which adaptation to the best perception takes place. In other words, the effect of each new stimulus is to produce an

adaptative organization of the organism's receptor instruments. Orientative reflexes constitute a special organization of the organism's reflective activity whose appearance is based on the activation of unconditioned connections that are set into motion by environmental influences.

Experiments involving the removal of the cortex of the large hemispheres in animals have shown that the physiological mechanisms of these reflexes are localized in the subcortex, which is proof that old phylogenetic forms of organizing living creatures' reflective activity are manifested in them. There are grounds for supposing that the predecessor of the orientative reflex is a still more elementary form of organizing higher nervous activity that I.P. Pavlov calls the "reflex of natural cautiousness."

This more primitive form of organizing psychic activity is manifested in the inhibition of the entire organism in response to every sufficiently intensive variation in the environment. One of the proofs of the phylogenetically earlier origin of this form of organizing psychic activity is the fact that it is widespread among lower animals. Thus, unconditioned-reflex attention, as a form of organizing the organisms reflective activity that relies on the functioning of subcortical mechanisms, is manifested in such unconditioned reflexes as the reflex of natural cautiousness and the orientative reflex, which are reflexes that change from one form to another.

The orientative reflex plays a special role in the organism's vital activity. It acts as one of the mandatory conditions for the formation of vew connections. An important regulatory role with respect to the orientative reflex is played by the cerebral cortex, which inhibits orientative reflexes in response to stimuli that are not of biological significane for the organism. The role of the cortex in the dying away of orientative reflexes has been proved by the research of I.P. Pavlov and his school.

Thus, although the physiological mechanisms of the orientative /92

reflex are located in the nearest subcortex, their normal functioning is still based on the interaction of the cortex and subcortex. Without intervention by the cortex, the orientative reflex loses its qualities of plasticity and variability and becomes a constant stereotyped response to any sufficiently strong stimuli, regardless of their significance for the organism.

The emotions of hunger, sexual drive, fear, anger, etc. also appear at the subcortical unconditioned-reflex level of reflection. These states are always characterized by a focusing of attention on the objects that can satisfy the hunger and sexual drive or that cause the fear, anger and other affects. Thus, we have every reason to believe that the physiological basis of emotions is the subcortical dominants, which, in the opinion of A.A. Ukhtomsky, may appear at various levels of the nervous system as a result of the interaction of the basic nervous processes. They constitute "... a more or less stable focus of increased excitability of the centers, no matter what has produced this focus, and new excitations coming into the centers serve to intensify (confirm) the excitation in the focus, while inhibitory phenomena are widely developed in the rest of the central system" [9]. Naturally, in the process of satisfying needs these dominants should be inhibited by the excitation coming from the internal organs, which should be accompanied by relaxation, a feeling of satisfaction and the diversion of attention from the object of the emotions.

"The second level of higher nervous activity," writes I.P. Pavlov, "is the large hemispheres, but without the frontal lobes. Here, with the aid of a conditioned connection, associations appear. This represents a new principle of activity: signalling of a few unconditioned external agents by an innumerable number of other agents, which at the same time are constantly analyzed and synthesized and which make possible very great orientation. This constitutes the only signalling system in the animal organism, and the first in man" [10].

Thus, as we can see, at the level of the first signal system involuntary conditioned-reflex attention appears; it is based on

the functions of the cortical mechanisms of the first signal system. /93
Involuntary conditioned-reflex attention is manifested most graphically in the so-called orientative reactions. As is well known, along with the orientative reflexes of unconditioned origin there are conditioned orientative reactions, which have been studied in detail by the Pavlovian school and in particular by A.G. Ivanov-Smolensky, one of its members, and which appear during the formation of conditioned reflexes. The essence of these conditioned reactions lies in the fact that after several combinations of an indifferent stimulus with the provision of food, the animal first turns toward the conditioned stimulus and then to the place where the food appears, i.e., in a definite sequence determined by the functioning of the conditioned connections the animal changes the posture of his analyzers with respect to some stimuli at one moment and with respect to others at another moment. Thus, a new and special organization of the reflection of objective reality appears. In response to the effect of stimuli from the external world, the organism's reflective activity is restructured and organized beforehand, in accordance with the conditioned signal. This way of organizing reflective activity is determined entirely by the sequence and relationship of the influences from the external environment. Here the external stereotype makes its imprint on the organization of reflective activity.

At the same time, the breakup, development and maintenance of dynamic systems of conditioned connections constitutes great nervous labor (Pavlov) that involves the emotions that now appear in response to the conditioned signal. Emotional tension anticipates the action, by mobilizing beforehand the resources of the organism that are needed in order to carry out the impending activity, which leads to the development of an emotional posture, or of readiness to carry out the actions in accordance with the image conceived. The latter acts as the regulator of involuntary activity.

The first-signal level of reflection is marked by the appearance of "image feelings," which express the organism's attitude toward the environment; this attitude is integral, active and complicated by acquired experience. The dominant nature of the image

is a necessary condition for its mobilizing and controlling effect on behavior. If this condition is met, the first-signal constellation of excited centers that is connected with the image will have an inhibiting effect on the unconditioned-reflex emotions, while simultaneously becoming stronger thanks to them. When there are no first-signal dominants organizing and directing the work of the brain, /94 emotions and the subcortical centers connected with them may become dominants and exert their influence on the performance of activity.

In the research done by E.A. Asratyan and his colleagues, which was reported to the 18th International Congress of Psychologists, it was experimentally proved that the defensive unconditioned reflex produced by applying an ESS to a dog's paw gradually changes to a fairly differentiated conditioned reaction, which reliably protects the dog from pain.

In the works of staff members of this laboratory, we find confirmation of the thesis that in the process of the organism's vital activity, inborn unconditioned-reflex emotional reactions begin to be controlled by cortical first-signal images, and there are grounds for believing that when an emotion-producing factor (in this case an ESS) is first used, dominants are created in the subcortical formations, but subsequently the emotional excitations become a subdominant that serves to feed the foci of optimum excitation in the cerebral cortex.

The determination by A.A. Ukhtomskiy of the conditions for and attributes of the appearance of a dominant state should be considered the heart of his doctrine concerning dominants. These conditions and attributes are the following: increased excitability of the nerve formation, its capacity to summarize the excitations that come to it, and a definite stability and sufficient inertia as qualities of these processes. More detailed further studies of dominants done by the followers of Ukhtomskiy have made it possible to establish as well such characteristic attributes of dominants as increased lability and increased capacity of the dominant focus to master rhythm. These fundamental propositions concerning dominants are of substantial

importance for finding out the basic objective regularities that govern their appearance and development. A.A. Ukhtomskiy showed that inhibition of the dominating foci may be accomplished through the action of exogenous and endogenous factors and through excessive reinforcement of outside stimuli. He established that when a dominant that has been experienced dies away, it does not disappear without a trace. The focus that it leaves behind subsequently helps the dominant to appear again. This property of the dominant shows its dependence on temporal connections, which is manifested in the fact that any conditioned stimulus involved in the formation of the dominant can produce it again, and in that case its appearance proceeds under easier conditions. Thus, on the one hand a dominant is a necessary condition for the formation of temporal connections, and on the other hand it makes its appearance during the functioning of these connections. "Until now the dominant produced was a condition for the appearance of I.P. Pavlov's temporal connection," writes A.A. Ukhtomsky, "but now it is a result of this connection, which has been sufficiently strengthened." /95

These properties of dominants reveal the nature of emotions, which on the one hand act as a necessary condition for the formation of new connections and, on the other hand, are themselves produced thanks to the existing connections. Special studies of the inertia of dominants done by Ukhtomskiy have made it possible to establish the existence of phenomena of exaltation during the gradual dying away of a stimulus that has produced a dominant.

The inertia of dominant processes is one of the basic factors in the stability and regulation of behavior. It becomes the mechanism of persistence, tenacity, concentration and other volitional qualities.

It may be assumed that the capacity of a dominant to summarize the reinforcements of excitations coming from outside sources and to intensify their rhythms is related to the emotional effect of musical works, whose rhythm under certain conditions may come to dominante and regulate a person's activity.

The research of A.A. Ukhtomskiy, I.A. Vetekuv, N.V. Golikov, M.N. Blatov, D.G. Kvasov and other members of this school has revealed the regularities governing the formation, development and functioning of dominant constellations of excited centers, which have a general rhythm of operation and which determine at a given moment the direction, organization and regulation of the organizm's activity.

A dominant acts as a central mechanism and mobile element that subordinates, organizes, integrates and coordinates the brain's reflex activity. At the same time, integral images of objective reality are formed during the functioning of a dominant, and behavior is structured and regulated in accordance with these images.

Experimental and theoretical work on the principles of dominants has led to the development of a doctrine concerning dominants in which they are understood as "general working principles of the operation of the nervous system," to which its activity is subordinated at various levels of phylogenesis.

In characterizing the third and higher level of higher nervous activity, I.P. Pavlov writes: "In man there is an additional signalling system, signalling by means of the first system - speech. This introduces a new principle of nervous activity - abstraction along with summarization of the innumerable signals of the preceding system, in turn once again with analysis and synthesis of these new summarized signals - a principle that makes for unlimited orientation in the surrounding world and that creates, as man's highest adaption, science both in the form of ordinary empiricism and in its specialized form" [11]. /96

Based on the characterization of the second signal system given by I.P. Pavlov, one may say that at this level of higher nervous activity its organization and regulation are qualitatively new, and the principal new feature is voluntary influence by man, in the process of reflection, on the objective reality that surrounds him, influence that is planned, expedient and directed by speech.

Voluntary attention appears at that level of man's development at which speech, as the signal of signals, becomes a factor that organizes and regulates his psychic activity. The role of speech in voluntary attention becomes completely clear in light of the doctrine of the classics of Marxism-Leninism concerning the unity of language and consciousness. Language, write Marx and Engels "...is practical and actual consciousness that exists both for other people and only in this way for myself as well ..." [12].

While language is a means of communication among people, it is at the same time a tool of struggle and of the development of society. Language is directly connected with production activity and with any other kind of human activity in all spheres of human life.

The Pavlovian doctrine concerning the two signal systems is in accord with these propositions of Marxism. Voluntary attention, as a specifically human form or organizing reflective activity, is inseparately connected with the functions of the second signal system and with its interaction with the first signal system.

In regulating and controlling in the work process the exchange of substances between himself and nature, man "...at the same time accomplishes his conscious goal, which acts as a law in determining the method and nature of his action and to which he must subordinate his will" [13]. /97 Man's work actions are always subordinated to a work goal of which he is consciously aware and that is consequently refected in speech. The existence of a conscious goal in human activity makes it planned and voluntary activity. In the work process man resists the reality surrounding him as an organized natural force that acts on nature and changes it in accordance with its goals. It is precisely this activity that gives rise to voluntary attention. Speech, which was brought into being by people's need to communicate in the work process, gave rise to a new and specifically human voluntary form of controlling and organizing psychic activity.

Voluntary attention, as a form of oraganizing and regulating psychic activity, operates in close connection with man's emotions

and needs and with the work that he does in order to satisfy these needs. Voluntary attention appears at that level of human development at which man begins to distinguish objects in the external world that serve to satisfy his needs, to give them names, classify them and take possession of them. Thus, the basis of the selective direction of man's attention lies in the conditioned connections that are imprinted in his brain and that are formed as a result of the effect on the brain not only of objects but also of words, those "signals of new signals." At this higher level of human reflective activity, at which people, using speech and abstract thinking, begin to distinguish external objects, to summarize and classify them, etc., mobilization, organization and regulation of human psychic activity may appear, even when a given object is lacking, with the aid of a word that signals the object, which is what makes man's actions voluntary.

In studying the physiological mechanisms of voluntary actions, I.P. Pavlov came to the conclusion that "the entire mechanism of volitional movement is a conditioned associative process that is subject to all the laws of higher nervous activity that have been described [14]."

Voluntary actions are causally determined phenomena. They seem to be free of causality and "spontaneous," but at bottom they are determined in a complex manner not only by the immediate but also by the long-range goals of being. In analyzing man's voluntary actions, I.P. Pavlov showed that the entire essence of voluntariness /98 consists precisely in a complex conditionality and that there is no absolute difference between voluntary and involuntary.

A voluntary action has its first basis in a first-signal conditioned reflex. With the appearance of the second signal system, when speech, in which abstraction and summarization are inherent, begins to act as a conditioned signal, the possibilities for voluntary regulation of activity are infinitely increased. The second signal system creates the conditions for the appearance of a qualitatively new kind of organization of the reflective activity of the

human brain, namely - voluntary attention.

Voluntary attention is inseparably connected with summarization and mediated reflection of objective reality, expressed in verbal form. This characteristic of voluntary attention provides it, as a form of organizing psychic activity, with enormous possibilities for affecting the formation and functioning of temporal connections.

The organizing and regulating effect of speech is clearly manifested in the emotional and volitional spheres of the human personality and in man's attitudinal feelings, in which may be reflected man's consciousness of the most diverse attitudes toward surrounding reality and toward himself.

L.V. Blagonadezhina correctly emphasizes that emotions and feelings constitute experiences involving correspondence and noncorrespondence between the objects and phenomena of reality, on the one hand, and people's needs and society's on the other. Depending on the nature of man's needs and on what in surrounding reality is of substantial importance to him, certain experiences take on dominating importance and corresponding force. Emotional experiences play an important role in regulating human activity. While emotions are always situational, feelings can be both situational and stable. Genetically speaking, the latter appear later. They are the result of emotional summarization.

Thanks to speech, a merger takes place between the emotional and volitional spheres of the personality. Unity and coordination in the functioning of the basic levels of higher nervous activity that have been described above, with the second signal system playing the leading role, are a necessary condition for the integrity of man's /99
behavior is manifested above all in the organization of his psychic activity and in the voluntary balancing and mastery of his feelings, emotions and effects. Disturbance of the normal interrelationships between the signal systems leads first of all to disruption of attention and to disorganization of both the volitional and the emotional spheres of the human personality.

Thus, man's normal psychic activity is characterized by coordinative interaction of the different kinds of attention and the states of feeling that correspond to them, whose appearance depends on the conditions of man's life and activity; in this regard, the dominating and regulating role belongs to voluntary attention and to social, ethical, aesthetic and moral feelings, which are the basic regulator of man's conscious behavior.

What has been said above gives us grounds for believing that the basic mechanism of the functioning of the emotional-volitional sphere of the personality is the dominants, which appear and interact at various levels of higher nervous activity.

It is possible to trace the genetic interconnection among the mobilizing, organizing and regulatory functions of the brain by analyzing the process of satisfying the need for food. A shortage of nutritous substances leads to a change in the composition of the blood, which in turn automatically activates corresponding nerve formations that I.P. Pavlov called the "food center." "It is perfectly clear," he wrote, "that the first impetus for the activity of this food center, which makes the animal move, get food and secrete saliva and gastric juice, comes from the chemical composition of the animal's blood when it has not eaten for several hours; its blood gradually becomes 'hungry' [15]."

The food dominant gives rise to orientative activity, i.e., to unconditioned-reflex attention, and draws into its sphere of influence an entire constellation of sensory, motor, vegetative, secretory and other centers, whose combined activity is regulated by inborn systems of connections that function in a stereotyped manner. If the need for food is satisfied, the emotion dies away and the organizing and regulating functions connected with it are inhibited. If the need is not satisfied, the emotional excitation is intensified, and this leads to new cycles of instinctive actions that are repeated in a stereotyped manner. Emotional behavior of this kind may be observed in /100
newborn animals and hungry children during their first days of life. The basic elements of the structure of their behavior are emotion-

producing movilization of the organism's internal potentialities, unconditioned-reflex orientation and organization of reflective activity, as well as involuntary and instinctive regulation of behavior, regulation that includes reverse efferentation.

In adult animals the state of hunger is mediated by the first signal system, which leads to a radical change in the nature of the interaction among the functions of mobilization, organization and control. Emotional excitation of the food dominant is now organized in involuntary conditioned-reflex attention, and control is accomplished with the aid of dynamic stereotypes and is directed by first-signal images, which act as dominating elements of the structure and serve as the regulator of behavior.

In man the need for food first of all activates the nerve formations connected with the emotion of hunger. The appearance of emotional states is accompanied by expressive movements and involuntary changes in visceral, vegetative and other functions. In the process of becoming conscious of this emotion, the feeling of hunger appears; this feeling serves as man's situational and conscious attitude toward the objects connected with satisfying his need for food. In his time, I.P. Pavlov correctly pointed out the qualitative difference between emotions and feelings. He wrote: "After all, an emotion is the work of an instinct, while a feeling is something else altogether, connected with difficulties in the activity of the large hemispheres" [16]. In another one of his works he again speaks of the fact that feelings are the result of the brain's conditioned-reflex activity, while emotions involve unconditioned-reflexes. This means that man's activity aimed at satisfying his need for food is organized in voluntary attention and is directed by a feeling that is based on the instinctive emotion of hunger. After consciously analyzing the situation that has arisen, man actively seeks means, ways and possibilities of satisfying his need, sets a goal for himself and voluntarily plans and carries out actions aimed at achieving it.

Conscious expedient regulation of behavior is governed by the laws of dominant relationships. As N.N. Megrabyan has very astutely

noted, the fundamental regularity governing man's emotional-volitional behavior consists in the fact that "the powerful inert flow of the subcortical component of affectivity is regulated by gnostic feelings and is directed along the course of reasonable necessity [17]." /101

Since we view emotions as the basal form of the personality's activity, on which are built up the organizational (attention), regulatory (volitional), motivational (feeling) and intellectual components of psychic activity, we should create conditions for living, working and learning that will promote the harmonious and comprehensive development of the emotional, volitional, motivational and intellectual spheres of the personality in their dialectical unity and interpenetration.

The system of theoretical propositions that has been set forth above could be called the dominant theory of emotional-volitional actions, which is a further development of the views presented in the works of Liper, D.B. Lindsley, S.L. Rubinshteyn, I.M. Sechenov, I.P. Pavlov, N.D. Ukhtomskiy, P.M. Yakobson and other authors.

The conception set forth above makes it possible to explain the types of human behavior under conditions of stress that have been found in the experimental study and, by systematizing the data obtained in the study, to may out ways of increasing the reliability of the operator's work.

In this connection, we should first of all subject to a more detailed and deeper analysis the tense type of operator behavior under experimental working conditions, which is the most widespread and clearly manifested type in our studies and which has also been described in the works of K.M. Gurevich, T.T. Dzhamgarov, A.V. Marishchuk, K.K. Platonov, V.V. Suvorova and other authors.

It may be assumed that in the case of this type the tension manifested in the movement of facial muscles, impulsiveness, constraint, disruption of coordination and excessive tension in carrying

out working movements is a consequence of the struggle of subcortical dominants. The painful shocks from the ESS, which are directed to the subcortex, lead to the domination of emotional defensive reflexes, which naturally produces hindrances and disorganizes the work. However, the feeling of responsibility for the results of the work and the striving to succeed in achieving the goal that has been posed activate second-signal dominants that are produced voluntarily. The test subjects express aloud their dissatisfaction, give themselves orders and try to mobilize their powers to overcome the difficulties involved in carrying out the assignments. Supressing the feeling of pain and discomfort, they strive in every possible way to work as accurately, quickly and reliably as possible.

It is not easy to win this victory over oneself. It requires /102
considerable nervous-psychic expenditures, and fatigue comes on rapidly. However, as the results of the studies using the emocoordinometer have shown, the tension in performing sensomotor actions that is observed in the case of the majority of the test subjects in this group gradually disappears as they perform exercises aimed at making the skills automatic. The sensomotor coordinations are carried out more and more confidently and easily and with fewer and fewer errors.

At the same time, in the case of certain group of the test subjects who took part in this series of experiments, not only was there tension throughout the training period, but it also clearly manifested itself when the subjects shifted to extreme working conditions.

Under tense working conditions and especially under battle conditions, every person inevitably experiences emotional tension, an alarm and apprehension concerning the outcome of events. However, under these circumstances people may behave differently. In this regard, D.A. Furmanov writes: "It is simply chivalrous twaddle to say that there are people who are completely calm in battle and under fire - there are no such people in the human race. One can become accustomed to appearing calm, one can conduct oneself in a dignified manner and one can keep oneself in check and not quickly give

in to the effect of external circumstances - that is another matter. But there is no one who is calm in battle or a minute before a battle, and there cannot be anyone like that."

What has been said gives us grounds for believing that tension in the performance by the operator of his functions is a natural reaction to the necessity of functioning under new conditions that involve overcoming difficulties. However, in the process of stereotyping actions and developing skills, the signs of tension disappear, attention becomes postvoluntary, the activity does not involve volitional efforts and it becomes more productive and more perfect. Awareness of successes achieved increases condidence in one's powers, and emotional experiences become sthenic.

In this connection, we should also take into account the data obtained from the studies done by G.F. Khlevnikov and V.I. Lebedev, who, by studying the dynamics of emotional-volitional processes during parachute jumps, established that, thanks to training of volitional /103 processes, after repeated jumps emotional phenomena as manifested in a sharp increase in pulse rate, emotional depression, limpness of movements, excessive tension, agitation, a feeling of alarm, a lack of confidence, etc. gradually begin to fade.

"The parachutists gain confidence in themselves and acquire the skills involved in coordinating their movements during free fall and the capacity to keep track of the time. Their emotions related to the danger begin to take on the character of the sthenic battle excitation connected with the activation of conscious activity" [18].

Success in carrying out the training assignment is very important for developing the strong volitional qualities that a person needs to control his emotions. When one's actions are unsuccessful and erroneous, negative emotions and a feeling of tension and dissatisfaction inevitably appear, which may sometimes lead to affective disruptions.

At the same time, when the training is properly organized, reactions to dangerous situations may take the form of conscious and

positively colored emotional behavior.

With respect to this matter, we should express our complete agreement with the idea expressed by B.M. Teplov that "danger may quite directly produce an emotional state of a sthenic type that is positively colored, i.e., that is connected with a particular kind of enjoyment and that increases psychic activity [19]."

As studies done by L.I. Tomashevskaya, A.Ts. Puni and others have shown, in work under extreme working conditions, emotional tension anticipates the action, and this serves to create a certain posture or readiness to perform the impending work. Guided by the expectations that he has, a person voluntarily rouses his powers beforehand, measuring them against the impending load. Regulation of these efforts is accomplished at the level of thematic feelings with the aid of an operative image.

As our studies using the emocoordinometer have clearly shown, the person usually overestimates the size of the expected load; therefore, his first actions are performed with excessive vigor. The viewfinder moves outside the emocoordinometer's working target area. /104
The person makes errors, and correcting them makes the viewfinder go out of the target area again, this time in the opposite direction.

Thus, a state of tension in performing sensomotor coordinations is objectively manifested in oscillatory movements of the viewfinder close to the target area along a harmonic trajectory. It is interesting to note that trajectories of this kind may be observed during the initial stages of training in driving an automobile and in piloting an airplane, a ship and other means of transport.

Consequently, the emotional tension that appears naturally during the initial stages of training serves to express the active involuntary mobilization of a person's efforts, efforts that are extremely necessary for the acquisition of new experience and that are aimed at overcoming the contradictions and difficulties involved in this. At the same time, in cases in which these contradictions are

not successfully resolved, emotional excitation becomes stagnant, and this has a negative effect on the execution of work activity and any other activity.

In daily life, emotions change their sign as the needs that produced them are satisfied, and this leads to a relaxation of emotional states. However, in cases in which emotional behavior does not lead to the satisfaction of the organism's needs, the emotion may become chronic and stagnant and may involve the appearance of a feeling of dissatisfaction, obsessive images, imaginary ideas, etc.

The long-term influence of stagnant subcortical dominants may become the cause of obsessive neurosis, paranoid states and other psychic illnesses. This fact has been emphasized repeatedly by many authors. Thus, in a special work by I.P. Pavlov it was experimentally proved that the basic cause of the appearance of these psychic illnesses is a situation in which emotions are chronically unsatisfied.

"Let us take a person," writes I.P. Pavlov, "in whose emotional makeup a rather frequent aspiration to excellence predominates. But nature has not endowed him with any outstanding talents. Implacable reality has refused him what he has striven for: He has gotten neither laurels nor influence, but, on the contrary, a deserved rebuff, i.e., continuous mistakes. ...Now the absolute power of an idea, of a fantastic picture of imaginary greatness and imaginary successes, is revealed. Since an emotion lives on to the end of the subjects's life, the sick idea exists along with it. We have before us true paranoia [20]." /105

As studies done by P.K. Anokhin, I.V. Dovidovskiy, Kh. M. Levina and others have shown, the presence of stagnant subcortical emotional dominants involves chronic changes in the activity of the cardiovascular system, the development of hypertonic phenomena, attacks of stenocardia infarcts, stomach ulcers and other illnesses.

It is well known that sudden and strong emotional shocks can lead to serious disturbances in a person's psyche.

All this shows the negative side of emotions. At the same time, their positive role and significance in human life is immeasurably great. The importance of emotions is especially great in human labor, in which they serve as a source of strength, creativity, initiative and persistence, which ensure the successful achievement of the work goals that have been consciously posed. Speaking of the significance of emotions in man's creative labor, V.I. Lenin emphsized that "grasping the truth is impossible without emotions."

Since he believed that human life consists in pursuing goals of all kinds and that emotion, as manifested in the goal reflex, is the basic form of vital energy for each of us, I.P. Pavlov correctly pointed out the need to foster, instill and develop purposefulness as an extremely precious quality of the working personality.

The correctness of the hypothesis that we have been developing is clearly confirmed by psychological analysis of the work of the test subjects who showed the pregressive type of behavior under extreme working conditions. They significantly improved their basic work indicators under these conditions. They worked with few words, thoughtfully, in a planned manner, at a calm pace and with minimum expenditure of strength. The majority of them worked without constraint and cheerfully, while experiencing enjoyment and the exhilaration of battle. A characteristic feature of progressive operators is their quick grasp of and adequate orientation in a situation, which enables them to develop a clear and adequate picture of a situation that arises. By concentrating his attention on the crucial and decisive attributes of the situation that has arisen, the operator quickly finds the necessary solution and immediately takes practical steps to implement it.

Of indubitable interest in this regard are the results of conversations held with supervisory personnel of power systems who had repeatedly been directly involved in preventing and putting an end to emergencies. Thus, one of them, T.P., gave this response to our request that he describe his state and behavior in emergency situations: "When I began working at the control panel, I was tense all the time /106

and I was afraid of making an error, knowing that this could cause emergencies and catastrophes; therefore, I acted indecisively, slowly and sometimes not entirely correctly. Later I got used to evaluating rather quickly the situation that had arisen, and, what is most important, not making hasty and unconsidered decision. At such times I usually give myself an order: Don't hurry, think it over calmly and find a way out of this situation. A good, merry song, a joke and humor in general help a lot. They lift the tension, divert my attention and help me to thank. My comrades have learned that if I begin to sing a song softly, then an emergency is at hand."

S.A., an outstanding pilot who has many years of experience, gave the following answer to our question concerning the emotional stability of pilots: "I have had occasion to come in contact rather often with good pilots who behaved courageously under battle conditions, did not become flustered and found a way out of the most complicated situations. In the majority of cases, their behavior on the ground was rather slow and phlegmatic. They didn't say much. However, as soon as they sat behind the controls of a plane and took off, they literally merged with the aircraft, subordinated it to their will and carried out the most complicated maneuvers at maximum speeds, while simultaneously observing the enemy and opening fire at the necessary moment. These were bold men of the air. During flight they experienced enjoyment and the exhilaration of battle."

What has been said makes it possible to draw the conclusion that strong moral-volitional qualities are the basic factor that make the operator's behavior under conditions of stress effective. It may be assumed that in this case the second-signal dominants not only neutralize the effect of the stress-factors, but also make adequate use of, i.e., are fed by, the emotional subcortical subdominants.

Thus, in the case of the test subjects whom we placed in the progressive group, emotions act as the basal forms of personality activity, on which are built the personality's volitional and motivational components of work activity.

Feelings and will, whose appearance is based on emotions and /107

which develop thanks to emotions, at the same time serve as the basic means of a person's conscious organization and self-regulation of his work behavior.

The behavior of "cowardly" test subjects may be explained by the domination of the instinct of self-preservation when self-control is diminished. We find graphic examples of such behavior in the work of K.M. Gurevich and V.F. Matveyev. "...When a serious emergency arose at a large hydroelectric power station, and as soon as the signals reporting the accident began to appear on the control panel," they write, "The operator on duty who was in charge of the station, hurriedly left the premises. About a half hour passed and other station personnel were able to put an end to the emergency. After that the operator on duty returned. He explained his absence in this way: He had spent the time in the men's room, which he had been unable to leave for some unknown reason [21]."

In another part of the same work, the following characterization is given of an operator who experienced obvious difficulties in organizing his cogitative activity during emergency training sessions and tried to procrastinate, in order to avoid having to undertake a purposeful search for solution. This operator tried to camouflage his fear with unconfident, contradictory and verbose communications.

Under the influence of fear, "cowardly" operators begin to act according to the accustomed routine, which is not adequate to the situation that has arisen. Their actions are stereotyped and thus inadequate.

Thus, despite the variety of the techniques, methods and contrivances to which representatives of the "cowardly" type resort, they are all characterized by a fear of excessive tension, which is expressed in their striving to extricate themselves at any price from the difficulties created by the emergency situation. It may be assumed that here the instinct of self-preservation predominates over the sense of responsibility and the desire to take part in solving the problems confronting the operator, while actively struggling

against and resisting the stress-factors.

We should emphasize a fact of no small importance: The "cowardly" type of behavior is found under certain circumstances not only in the case of novices, but also in the case of workers who have many years of experience. Obviously, under optimum working conditions such operators can handle their duties, but a state of fear arises in especially critical and complex extreme situations. Our experiments show that the members of this group can be rehabilitated when they are given outside help in overcoming their fear and when the necessary volitional qualities of the personality are instilled in them . /108

It is much more difficult to rehabilitate representatives of the inhibited type. Obviously, this is because in this case we are dealing with a manifestation of the induction relationships of the dominants of the cerebrum.

The person's awareness of the full complexity of his actions in an emergency situation and of his responsibility for their results leads to excessive excitation of the nerve centers, which, in accordance with the laws of induction relationships, inhibit the manifestation of emotions. The cortex thereby deprives itself of the "source of its strength." As a result, the activity of the personality is sharply diminished and complete apathy, resembling a state of shock, ensues.

The aggressive-uncontrolled type of behavior is the direct opposite of the inhibited type of behavior. We have every reason to believe that in this case the affective dominants predominate and the proper volitional regulations are lacking. Affective disruptions may not be observed in ordinary situations. Usually they appear under difficult working conditions, and the tendency toward aggressive-uncontrolled actions is manifested in different individuals in different ways and for different reasons.

In all probability, the individual differences among the representatives of this type are determined by the regularities governing

the interconnection and interaction between the cortex and the subcortex. Naturally, further work on the problems of the reliability of man's work will require that research projects be undertaken aimed at ascertaining the reasons for the decisive conditions and factors that taken together determine to which type a person belongs.

In concluding this section, we should examine the following question, which has arisen quite legitimately: Is there a relationship between the strength, mobility, equilibrium and the other characteristics of higher nervous activity, and the types of behavior under conditions of stress that have been described above?

Since we do not have our own data, we can turn to the recent works by V.D. Nebylitsin, who is a leading specialist in the study of reliability and or the typological characteristics of higher nervous activity. He correctly notes that the functioning of the cerebrum involves a system of overall control, which carries out the general regulation of the actions, states, predispositions and other functions of the organism, and a receptor system, which performs the function of analyzing afferent signalling and synthesizing the products of signal-processing in images of reality. /109

A considerable number of studies have already been devoted to studying the functional properties of the receptor system and some of its analyzers. There are methods for determining the strength of the excitative and inhibitory processes, their balance and mobility and other properties of the receptor system. At the same time, V.D. Nebylitsin emphasizes, the answer to the question "must the functional properties of the structures of the regulatory system necessarily coincide or even correlate at all significantly with the functional properties of the formations of the receptor system" probably should be in the negative [22].

While we agree completely with this statement by Professor Nebylitsin, we should merely add that, in all probability, the decisive role in man's emotional-volitional sphere belongs to the overall functions of the brain organs that carry out voluntary and invol-

untary regulation of work activity, functions that are formed and improved through training. Thus, not the inborn properties of the nervous system inherent in the receptor functions, but rather the characterological, purely human forms of personality activity that manifest themselves most clearly under extreme working conditions come to the fore.

Very recently the emotional stability of the operator's work at a control panel in power systems has been studied by K.M. Gurevich, M.S. Gadzhiyev and other authors, who have tried to establish a connection between the emotional stability of operators and the typological features of their higher nervous activity. However, because of a whole series of methodological difficulties, the authors of these studies failed to prove the existence of a direct relationship between the strength, mobiligy and equilibrium of the basic processes of the receptor system and the emotional stability of the operator in his work.

Thus, we have every reason to believe that the existence of a direct connection between individual differences in man's receptor characteristics and his work reliability indicators is not very probably. At the same time, it may be considered an established fact that individual differences in the overall characteristics of the sturctures of the brain's regulatory system do affect reliability. /110

Psychological studies and experience in life indicate that a person whose nervous processes are very strong and sufficiently mobile but who does not have the proper volitional qualities, such as self-possession, persistence, self-control, the ability to think things over soberly, the ability to suppress fear, etc., may become flustered in emergency situations, make mistakes and conduct himself as a not very reliable element of the man-machine system. Emphasizing the decisive role of upbringing in forming the emotional-volitional sphere of the personality, I.P. Pavlov wrote: "A hothouse atmosphere in upbringing can lead to a situation in which a person with a strong nervous system remains a pitiful coward for his entire life.[23]."

On the other hand, by means of purposeful self-upbringing even a puny and physically weak person, like the great Russian commander A.V. Suvorov was, can become a sober-minded and courageous man who scorns danger, has a magnificent command of his feelings and emotions, uses them masterfully to lift the spirit of the Russian army and inspires it to victory under the most difficult battle conditions.

WAYS OF INCREASING OPERATOR RELIABILITY

Summarization of the results of the theoretical and experimental studies presented in this work makes it possible to draw a number of conclusions dealing with increasing the reliability of the operator's work in the system "man-automated device."

The first of these conclusions is the product of statistical treatment of the data obtained from the first and second series of studies.

Analysis of these data show convincingly that when the test subjects participating in the experiments were subjected to the emotion-producing factors, performance of the sensomotor coordinations became considerably worse in the case of about 29% of the total number of subjects. This fact indicates that it is necessary, in order to increase the reliability of the work of the system "man-automated device," to carry out a psychological selection of candidates on the basis of the indications of their reliability. In this connection, there is the question of the methods and criteria to be used in the psychological selection of operators who possess the necessary emotional and volitional qualities.

The experience that has been gained in the practical utilization of the emocoordinometer method that has been described in this work gives us grounds for recommending it, after the appropriate correctives have been applied, for use in selecting operators who operate various vehicles - pilots, drivers, railroad engineers, drivers of electric vehicles, etc.

Soviet psychology has definite achievements to its credit in

developing methods for the psychological selection of pilots, motor-vehicle drivers and cosmonauts. We have methods for putting together groups of operators who are psychologically compatible.

On the basis of study of the working conditions of pilots as well as of operators who control certain complex systems, staff members of the Ukraine Republic Institute of Psychology have developed and tested a set of very effective simulation methods intended for the psychological selection of personnel for these specialties. This set of methods includes tests that are used to determine the applicants' individual characteristics with respect to thinking, attention, memory and sensomotor capacities, as well as their emotional-volitional and intellectual qualities. Psychological selection of pilots insures a reduction in the proportion of dropouts due to poor progress in flying from 27-30% to 4-5%. Carrying out this kind of selection saves a considerable share of the funds that are spent on instruction, raises the quality of vocational training and reduces considerably the number of accidents and catastrophes.

If one considers that according to simplified calculations done by American scientiest $150,000 is saved for each properly selected specialist, the economic gain from using psychological selection methods in aviation should come to hundreds of millions of rubles.

In the process of studying the problem of vocational selection, Soviet psychologists have succeeded in establishing a system of theoretical principles on the basis of which it is possible to develop very effective methods of diagnosing the vocational capabilities necessary for successfully mastering any technical specialty. There is reason to believe that thanks to this research, the foundation has been laid for a psychological theory that will make it possible to carry out the purposeful development of psychological selection methods for operators of any type.

The second way of increasing the reliability of the operator's work is through improvement of the content and methods of vocational training, improvement that would insure, along with the formation of /112

the knowledge, abilities and skills needed by the operator, the inculcation of the emotional-volitional and moral qualities that are vocationally significant.

Unfortunately, we must state that the present systems of vocational training for operators not only do not take into account but often completely ignore the need for developing and cultivating the emotional-volitional sphere of the pupils' personalities, which is subsequently reflected in lower work reliability indicators.

Naturally, what has been said makes us think of the need for developing new and more effective systems of vocational training that would insure the proper development of the vocationally important personal qualities of the pupils.

In developing more refined methods of operator training, we should also take into account the instances found in our studies of both the positive and the negative effect of emotions on the formation of sensomotor abilities and skills.

Summarization of the experimental data obtained also gives us grounds for believing that one of the ways of increasing the operator's imperviousness to hindrances is to have him form automatisms that could be used in stressful situations.

However, this way of increasing the reliability of the operator's work is inapplicable in cases in which unforeseen emergency situations arise to which a solution cannot be found by stereotyped means.

It is obvious that in this case it is possible to insure that the operator will function reliably by developing in him the volitional qualities that promote the conscious organization of activity, the suppression of sthenic emotions that disorganize activity and the transformation of these emotions into a factor making for the conscious mobilization, regulated by speech, of powers aimed at adequately assessing the situation that has arisen and at finding effective means and methods of solving the operative problem.

Success in carrying out the practice assignment is of great importance for developing strong volitional qualities. When the person's actions are unsuccessful and erroneous, negative emotions and a feeling of tension and dissatisfaction inevitably appear, which sometimes may lead to affective disruptions.

At the same time, when the training is properly organized, reactions to dangerous situations may take the form of conscious and positively colored emotional behavior. /113

What has been said enables us to conclude that one of the principal ways of increasing the reliability of the operator's work under conditions in which he is subjected to stress-factors is to instill in him the personal volitional qualities that will enable him not only to suppress emotions, but also to control them by transforming them into a source of strength and energy.

Thus, solving the problem of operator reliability is closely connected with improving the system, programs and methods of his vocational training for operators. It should be noted that unfortunately methods of training operators being used at the present time do not insure the formation of the emotional-volitional sphere of the pupils' personalities, which naturally has a negative effect on their work reliability indicators.

A technological system for work and vocational training that has been developed and tested by Ukranian scientists and that insures favorable conditions for the comprehensive developement and upbringing of the pupils as they master in an integrated manner design-technical, organizational-technological and operational-monitoring abilities shows great promise for accomplishing the tasks involved in inculcating the personal qualities that are vocationally importnat for an operator.

Many years of testing this system have shown that it helps to cultivate the emotional-volitional qualities of the personality and to inculcate a creative attitude toward work and independent initiative on the part of the pupils aimed at improving the work process and

the products of the work.

An individualized approach to the pupils based on consideration for the characteristic features of their behavior that are manifested under extreme working conditions is a necessary prerequisite for worthwhile vocational training. For example, in order to eliminate excessive chronic tension, it is possible to use exercises aimed at mastering controlling actions and making them automatic, diversion of attention to outside signals, jokes, and the performance of special physical exercises. The difficulty of the assignments should increase gradually. Instructions and directions should be given softly and in a few words. Crude actions that insult the pupils' dignity must not be used under any circumstances.

The psychological climate in the collective of instructors and students should be such that it promotes the inculcation of friendship, comradeship, mutual aid and a feeling of responsibility for carrying out the assigned task.

Psychogenic training combined with deep breathing a a slow rate may yield good results. A special role in training "tense" pupils is played by the formation of the habit of functioning under any conditions in a thoughtful and planned manner, as calmly and confidently as possible, without becoming flustered and without shirking difficulties.

Different techniques are used to rehabilitate the representatives /114
of the "cowardly" type of behavior. Here an authoritarian style of leadership comes to the fore; the instructor should strive to make the student do his bidding by means of loud orders and sharp actions. The instructor's personal example, his ability promptly to come to the aid of a pupil who is trying to overcome the difficulties standing in the way of achieving the goal, and an ironic attitude toward danger create the necessary prerequisites for inculcating self-confidence and discipline, for suppressing fear, for kindling initiative and for developing the capacity for conscious self-regulation of behavior.

What has been said indicates the need to develop special didac-

tic means, techniques and methods of vocational upbringing for operators that will take into account the individual features of their behavior under different working conditions.

The third possibility for increasing the reliability of the operator's work can be realized by creating the most favorable psychological climate and by optimizing his working conditions.

Proceeding from the dominant theory of emotional-volitional actions, we should first of all review with a critical eye the established ideas concerning the role and importance of emergency signalling.

In the design of control panels for industrial, power, transportation and military facilities, extremely sharp emotion-producing signals are usually used as indicators of an emergency situation: Deafening bells, wailing sirens, blindingly bright flashes of light and other very strong stimuli.

Perhaps not without reason, panel designers believe that every emergency signal should in a certain manner state, signal, model and cry out about the danger of the situation that has arisen, thereby attracting the attention of the operators.

At the same time, experience and special psychological studies /115
have shown that the use of very strong emergency signals often keeps the operator from concentrating on the cause of the emergency and sometimes even disorganizes his activity completely.

The reason for the negative effect of very strong signals is that they attract a person's involuntary attention and create in the subcortex intensive dominants that have an inhibiting effect on the cortex. A subcortical dominant that is free of control by the cortex may lead to various kinds of affective states.

It is obvious that in order to optimize the operator's work, we should use systems for indicating emergency situations whose signals

are not strong emotion-producing factors themselves and are addressed first of all to the voluntary conscious sphere of a person's activity.

For example, soft monotonic sounds that cease when an emergency situation arises might be used as danger signals.

In that case, the operator's attention develops in accordance with the laws governing dominant relationships after the stimulus has ceased to operate, and the insuing quiet helps the operator to perform his functions adequately.

In certain cases individual words, commands and brief instructions previously recorded on tape and played during an emergency situation might be used as danger signals; such signals not only mobilize the operator's voluntary attention, but also help him to orient himself in the situation that has arisen and to make the right decision promptly.

It is also important that the words of the emergency instructions are spoken rather loudly and in a calm and confident tone. In addition to communicating the nature of the emergency and possible ways of putting an end ot it, such instructions should include information about how the operator should conduct himself in the emergency situation.

Laconism, expressiveness and optimum intensity in the case of the emergency signals, orders and instructions also serve to optimize the operator's working conditions.

An emergency signal should help the operator to orient himself in the situation and quickly to find the elements of the system that require attention and intervention first.

In order to increase the reliability of the operator's work, we can also use, in addition to the techniques described above for optimizing his objective working conditions, subjective directions to the /116
effect that, without becoming flustered, he evaluate the situation and calmly, confidently and competently find the solutions to the operative problems.

The most varied methods aimed at inhibiting the subcortical dominants in order to create new dominant foci in other areas of the brain may be used in order to overcome negative emotions. This can be achieved by means of both voluntary and involuntary diversion of the operator's attention from the emotion-producing factor that is affecting him at a given moment. Painful, tactile and auditory signals, as well as special physical exercises that counteract the effects of the long period of static tension of the muscles involved in the work, may be used as involuntary stimuli. The performance of breathing exercises at a slow rate may help to reduce emotional tension.

The major role in maintaining a person's emotional equilibrium is played by his volitional qualities, which are manifested in his ability to give himself orders that make him consciously control and adequately regulate his actions.

Voluntary switching of attention to thoughts and images that evoke positive emotions is an effective means of increasing imperviousness to hindrances. Finally, the most important condition for increasing the operator's imperviousness to hindrances and the reliability of his work is inculcating such emotional-volitional qualities as condidence in oneself, persistence in achieving the goal that has been posed, courage, self-possession and a sense of duty and responsibility for one's actions.

An ironic attitude toward danger and the ability to find comic moments and to sing a song, even during the most tragic situations, serve as an excellent means of maintaining self-possession, reasonableness and control over one's actions.

It is noteworthy and at first glance paradoxical that until recently the design of control panels for the most diverse systems has been oriented solely toward optimum working conditions.

This orientation fails to take into account the need for creating conditions that promote an increase in the reliability and effective-

ness of the operator's work in stressful situations. For example, on present-day airliners there are as many as 500 instruments, control levers, different indicators and other devices with which the pilot has to deal. Under optimum working conditions, when all flight systems are functioning normally, it is not especially difficult for the crew to insure that the flight proceeds normally.

However, in unexpected, sometimes extraordinarily complex and /117
crucial emergency situations, the pilot cannot make use of information coming to him through many channels. At such times, he is forced to operate intuitively, using the readings of two or three indicators. In this connection, it is extraordinarily urgent that new psychological principles for designing control panels for all working conditions be developed, panels that insure that the operator has optimum working conditions regardless of whether the situation itself involves optimum, minimum or above all extreme working conditions.

The idea of building such panels was first formulated in the works of B.F. Lomov, L.I. Prokhorov, Ye.T. Il'in and other authors, who insisted on the need for putting into practice the principle of the optimum dynamic regulation of the information being received by the operator, with due regard for his state at a given moment.*

As modified by us, the control panel for all working conditions in a modern airplane might be designed according to the following scheme. In addition to the piloting instruments, the sections of the control panel have a small group of indicators that provide information concerning a number of parameters that characterize (temperature, pressure, number of revolutions) the operation of any flight system. The pilot receives information concerning the optimum functioning of the plane's systems from a special indicator board that reproduces against a background of the plane's outline the location of the undercarriage, engines, fuel tanks, basic units of the hydraulic system and other units. Under ordinary conditions, when all of the basic systems involved in flight safety are functioning normally, green indi-

* This question is elucidated in detail in Ye.P. Il'in's article "Operative Rest and Optimum Regulation of a Person's Work Capacity," in this collection.

cators are lit in the places on the indicator board where these systems are located. If even one of the parameters goes outside the established limits, a yellow indicator that illuminates number and name of the unit that is not functioning properly lights up in the corresponding place on the instrument board. After that a group of monitoring insturments are manually or automatically hooked up to this unit, and simultaneously instructions are given concerning ways of putting an end to the pre-emergency situation. The pilot's task may be made even easier, if only the piloting instruments and a summarized arrangement of the indicators of the functioning of all the basic units are left on this instrument panel, and the monitoring instruments and the system for regulating these units are transferred to the flight engineer's panel. If this were to be done, we would achieve a rational and uniform distribution of functions among the crew members, thereby creating conditions that would promote an increase in the effectiveness and reliability of its work. While we realize very well that the principle of constructing control penels for all working conditions that has been described above is not the only, all-purpose means of optimizing the operator's working conditions, we still believe that putting this principle into practice will open up new possible avenues for humane treatment of the people who perform the extraordinarily responsible and complex functions involved in controlling new equipment. /118

The method that has been proposed by Soviet scientists for assessing, on the basis of engineering psychology, the reliability and quality of systems technology complexes may play an important role in the scientific quest for ways of further increasing operator reliability. The use of this method makes it possible to develop unified scales of nondimensional assessments that can be used to determine the class of a technical system in relation to the average potentialities of the people who control it, and simultaneously to find out what point total in assessing the level of an operator's qualifications should be considered passing, i.e., would insure the reliable and highly effective operation of the given systems-technology complex*

*See the article "A Machine's Psychological Data Sheet" in this collection.

The extensive use of methods based on engineering psychology for evaluating both currently functioning and planned systems makes it possible not only to optimize the conditions, structure and content of operator activity, but also simultaneously to resolve questions involved in their selection, training, upbringing and practice under different working conditions.

Making the operator's work healthful, joyful, creative, highly productive, rationally organized and as reliable as possible is one of the chief tasks of present-day psychology.

REFERENCES

1. Giss, R. Study of the Correlations Between Behavior and Brain Activity. In the collection: Vysshaya nervnaya deyatel'nost' (Higher Nervous Activity). Moscow, 1963.

2. Simonov, P. What Emotion Is. Nauka i zhizn, 1965, p. 3.

3. Stevens, S. Eksperimental'naya psikhologiya (Experimental Psychology). Moscow, Vol. 2, 1960, p. 668.

4. Stevens, S. Ibid.

5. Mileryan, Ye.A. Electrical Activity in the Human Brain During Attention to Sonic Stimuli. Voprosy psikhologii, 1955, p. 2.

6. Ushinskiy, K.D. Sobrannye sochineniya (Collected Works). Moscow-Leningrad, p. 224.

7. Pavlovskiye sredy (Pavlovian Environments) USSR Academy of Sciences Press, Moscow-Leningrad, Vol. I., 1948, p. 268.

8. Pavlov, I.P. Sobrannye sochineniya (Collected Works). Moscow, Vol. 3, Book 2, 1951, p. 214.

9. Ukhtomskiy, A.A. Sobrannye sochineniya (Collected Works). LSU Press, Vol. 1, 1950, p. 165.

10. Pavlov, I.P. Sobrannye sochineniya (Collected Works). Vol. 3, Book 2, p. 214.

11. Pavlov, I.P. Ibid, p. 214-215.

12. Marx, K. and F. Engels. Sochineniya (Works). Vol. 3, p. 29.

13. Marx, K. Kapital (Capital) Vol. 1, p. 185.

14. Pavlov, I.P. Sobrannye sochineniya (Collected Works). Vol. 3, Book 2, p. 229.

15. Sechenov, I.M., I.P. Pavlov and N.Ye. Vvedenskiy. Fiziologiya nervnoi sistemy (Physiology of the Nervous System) Vol. III, p. 168.

16. Pavlovskiye sredy (Pavlovian Environments) Vol. 2, p. 210.

17. Megrabyan, N.N. O prirode individual'novo soznaniya (On the Nature of Individual Consciousness). Yerevan, 1959, p. 107.

18. Khlevnikov, G.G. and V.I. Levedev. The Dynamics of Emotional-Volitional Processes During Parachute Jumps. Voprosy psikhologii, Vol. 5, 1964, p. 8.

19. Teplov, B.M. Uchenye zapiski MGU (Transactions of MSU). Moscow, No. 90, 1945.

20. Pavlov, I.P. A Test of the Physiological Conception of Obsessive Neurosis and Paranoia. Fiziologiya nervnoy sistemy (Physiology of the Nervous System). Medgiz, No. XIV, 1952, p. 576.

21. Gurevich, K.M. and V.F. Matveyev. Voprosy professional'noy prigodnosti operativnovo personala energosistem (Problems of the Vocational Fitness of Operative Personnel of Power Systems). Prosveshcheniye Press, Moscow, 1966, p. 24.

22. Nebylitsin, V.D. On the General and Particular Properties of the Nervous System. Voprosy psikhologii, No. 4, 1968.

23. Pavlovskiye sredy (Pavlovian Environments) Vol. 2, p. 588.

N75 17950

ON THE EFFECT OF EMOTIONAL STATES ON OPERATOR THINKING

A.V. Solodkova*

The present work is one of a series of studies of the problem of operator reliability that have been done in recent years by the Ukraine Republic Institute of Psychology. /119

Thanks to these studies, a theoretical concept has been formulated that explains the nature of emotions and elucidates their importance in man's life and work. This has made it possible to determine methodilogical approaches to studying the problem of reliability and, on this basis, to develop new methodological techniques whose use has made it possible to discover the regularities governing the effect of emotional states on a person's work capacity under conditions of stress. In this connection, we should first of all give a brief account of the basic tenets of this theoretical concept, on the basis of which the aims and methods of our study have been determined.

We have applied a system-structural approach to solving the problem of operator reliability. This approach presupposed that first a number of research projects be carried out aimed at studying the subjective and objective conditions, connections and relationships that determine the reliability of the performance of each of the structural elements of operator activity under instructional, optimum and extreme working conditions. These research projects had as their aim a subsequent shift to resolving questions of the overall reliability of the performance of the integral structure of this activity. Whereas in works of previous years we studied primarily questions of the reliability of the performance of sensomotor control functions, in this research project the principal object of study is the reliability of a person's performance of the cogitative operations involved in receiving and processing information while

*Kiev, Ukraine Republic Institute of Psychology.

being subjected to hindrances.

Just as in the other works, in this case as well reliability in performing intellectual actions was studied by comparing the test subjects' success indicators for solving operative problems under optimum and extreme working conditions (see Figure 1 on the inset opposite page 21). /120

The aim of these experimental studies consisted in ascertaining the nature of the effect on the operator's intellectual activity of of the emotional states produced by outside chromatic light, sonic and electric-skin stimuli. For this purpose we used the methods developed by Ye.A. Mileryan involving the use of the EMO-3 unit, which consists of a test subject's panel, an experimenter's panel and a programming device.

There are eight arrow indicators on the front section of the test subject's panel. The upper part of this section has a translucent screen for projecting the principle or algorithm to be used in solving a given problem. On the slanting section of the test subject's panel there are two levers - for the right and left hands. Each of these levers can be put in 5 different positions, which are designated by the numbers 1 to 10. The test subject can move the right lever into positions 1,2,3,4 and 5 and the left lever into positions 6,7,8,9 and 10.

The experimenter's panel has a tumbler switch for turning the system on, an on-off indicator, a switch for the type of work, buttons for starting and stopping the correct-answer indicator board, and three counters, which measure, respectively, the number of errors, the number of correct solutions to the problems and the total number of assignments presented to the test subject during the experiment.

The EMO-3 apparatus consists of the following basic units: 1) the program unit; 2) the unit for picking up and recording the answers; 3) the projection device; 4) the emotion-producing stimuli unit; and 5) the power unit.

The program unit of the EMO-3 is designed to present five series of problems, each of which contains eight problems. Each problem is presented by placing the arrows of the indicator instruments in the required positions and by displaying on the translucent screen the sequence to be followed in reading the instruments on the panel.

The emotion-producing stimuli unit insures that the test subject /121 is automatically subjected, in a sequence determined by the experimenter, to sonic stimuli of varying intensity and tonality, as well as to light stimuli in the 7 basic colors of the spectrum and to an ESS with an intensity of 50 to 150 microvolts. The light and sonic signals are sent by means of lamps covered by light filters and two speakers powered by a special generator.

Elastic ringlets fastened to the test subject's index finger and wrist are used to apply the ESS.

The study consisted of three series of experiments, in which 32 test subjects who were pupils in the upper grades at a number of schools in Kiev took part.

In the first series of experiments the test subjects had to solve 40 different problems. The essence of these problems was that in the course of his work on the apparatus the test subject, within the time allotted to him, had to read the instruments, do the necessary calculations in accordance with the principle given, make the corresponding decisions and carry them out my means of previously known differentiated movements of the levers.

Guided by the principle given, the test subject had to compute the algebraic sum of the readings of the instruments that were included in the sequence diagram for solving the given problem. In reading each instrument, first the value of each division of the scale was determined, and then the sign and absolute magnitude of the reading. The final result of the computation of the readings of all the instruments included in the sequence algorithm was expressed by a positive whole number from 1 to 10. Depending on the

result obtained, the test subject had to move one of the levers of the apparatus in a certain way.

Before the start of the test, the participants were given the following instructions: "The instrument panel of the apparatus in front of you has a window and eight arrow instruments. In the window you will be shown a diagram of the location of these instruments, in which a special arrow will indicate exactly which instrument readings should be used in the calculations, and in what order they should be done. Guided by this principle, you should quickly determine the value of each division, take the readings of the first instrument and then of all the others, and in this way find the algebraic sum of all the readings. The arrows of the instruments will move to the right or to the left of the zero position. When the arrow moves to the right, the reading of the instrument will be positive, and when it moves to the left the reading will be negative. /122
The sum obtained by means of algebraic summation must be recorded by an appropriate movement of one of the levers. The tests consist of eight complicated problems. You will have a limited amount of time to solve each problem. Before the actual tests, you will get used to working on the apparatus by solving practice problems."

When he was convinced that the test subject had mastered the instructions and the procedure for working on the apparatus, the experimenter gave the command "Attention" and after two or three seconds pressed the proper button for starting the program. When the eight problems had been done, the apparatus stopped automatically and the experimenter entered on a record sheet the results of the tests as recorded by the counters - the number of problems solved correctly and the number of errors made by the test subject. In addition, data from observations of the test subject's behavior during the experiments were also entered on the record sheet - his tension, decisiveness, confusion, attentiveness, impulsiveness of his actions, etc. There were special columns on the record sheet for the verbal statements of the test subject.

The same test subjects took part in the second series of experiments. But now as they solved each series of 8 problems, they were

subjected to sonic signals of varying tonality with an intensity of 65, 77 and 88 decibels.

In a third series of experiments, the test subjects solved similar problems while being subjected to an electric-skin stimulus of 40 or 80 microamperes whenever they made a mistake.

The record sheets of the experiments recorded the number of correct and erroneous solutions and the data from observations of the test subjects' behavior, as well as their answers to the following questions: 1) Which stimuli hinder you most in your work; 2) which problems are you failing to solve, and why; 3) how does the ESS affect you; 4) how does the sound affect you; and 5) what is your attitude toward the experiments.

The test subjects' inperviousness to hindrances was determined by comparing the results of their mental activity and the nature of their behavior under extreme and optimum working conditions.

* * *

Overall statistical analysis of the experimental data obtained, as well as the contruction of a graph, enabled us first of all to divide the test subjects into the following basic groups. The first of these consisted of 5 persons (15.6%), who, when subjected to the sonic and electric-skin stimuli, invariably increased the effectiveness of their mental activity, which was manifested in an increase in the number of correct answers and in a decrease in the number erroneous actions during the second and third series of experiments, as compared to these same indicators during the first series. /123

The test subjects in the second group showed a high degree of stability with respect to the indicators of their mental activity during all three series of experiments. It turned out that there were 6 persons in this group (18.8%).

We placed 21 test subjects in the third group. When they were

subjected to the hindrances, the reliability, accuracy and effectiveness of their mental activity dropped (65.6%).

Not limiting ourselves merely to ascertaining the data presented above, we considered it necessary to do a more detailed analysis of the causes and factors that increase, stabilize or reduce the effectiveness of a person's mental activity under difficult conditions. With this aim in mind, first of all we studied in greater detail the results pertaining to the first group of test subjects, who, when subjected to the hindrances, showed an increase in the effectiveness of their cogitative activity that varied among the different test subjects from 1.3% to 18%, with an average for the group of 7.6%. The data on the record sheets also indicate that a characteristic feature of the work of the members of this group was their ability to control themselves and to fight against the diversion of their attention. Voluntarily regulating and controlling their behavior, these test subjects not only successfully resisted the effect of the interfering factors, but even used this effect to increase their work productivity. As the experiments show, given certain conditions all these qualities can be developed through training.

For example, when test subject Vladimir G. was solving the first series of problems at the beginning of the experimental training, he was very agitated, his hands shook, he worked slowly, he was extraordinarily tense and he confused the signs and value of the divisions. He tried to help himself concentrate his attention by pointing his finger at the instrument with which he was working at the given moment. However, when solving the second series of problems, he was straining less, was better oriented and solved the problems more quickly, but he was still not attentive enough and confused the signs. At the end of the experimental training his behavior was confident and he was solving the problems easily and quickly. When subjected to the outside sonic stimuli, he solved the problems /124
quickly and accurately and his behavior was relaxed, although he sometimes blocked his ears with his fingers. He said that "in the beginning the sounds hindered his thinking, but later he tried to divert his attention from them and to forget about them, which in-

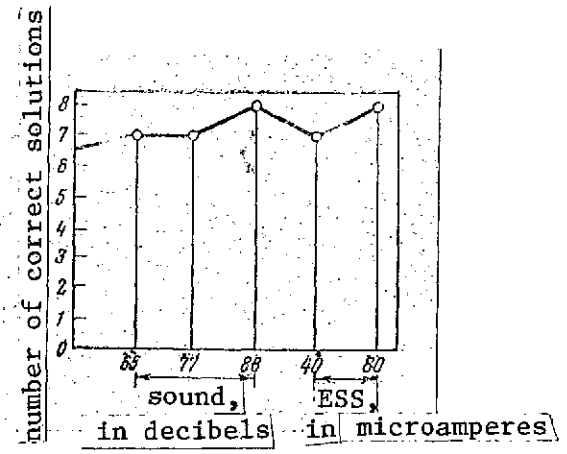


Figure 2. Graph of problem-solving by test subject V.G.

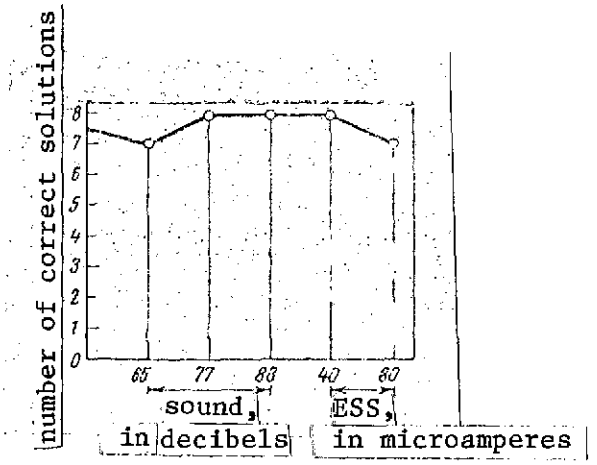


Figure 3. Graph of problem-solving by test subject V.I.

volved great efforts of his will, especially when the sounds became very loud." It is characteristic that it was precisely when the intensity of the sound reached its maximum level (i.e., 88 decibels) that Vladimir G. solved all 8 problems without any mistakes, as may be seen from the graph (Figure 2). He achieved the same results when he was subjected to the maximum ESS - 80 microamperes. The test subject said, "I am not afraid of the current, although I don't like it." During the experiments he behaved confidently, reacted to the shocks calmly and without panic and pressed on the levers boldly and without fear. As may be seen in the graph of Figure 2, the characteristic trend of the behavior of this test subject may be expressed by the following phrase: "The more difficult the conditions, the more effective his mental activity." Thus, whereas during the experimental training this test subject solved an average of 6.5 problems out of 8, when he was subjected to sonic hindrances of 65 and 77 decibels he solved 7 problems out of 8 correctly. When the intensity of the sound was increased to 88 decibels, there was a further improvement in his results. He solved all eight of the problems without a mistake. The same was true when he was subjected to the ESS. When he was subjected to a current of 40 microamperes, he gave 7 correct answers (out of 8), and when the strength of the current was increased to 80 microamperes the effectiveness of his cogitative activity also rose: he solved all 8 problems correctly. It is natural to assume that, as our previous studies have shown, if the strength of the hindrances were to be further increased, the effectiveness of mental activity might fall, down to the point of its complete disruption.

The behavior of another test subject in this group, Valery I., was somewhat different. At the start of the experimental training he was extraordinarily tense, he was agitated and poorly oriented with respect to the value of the divisions, he confused the signs and made a great number of mistakes (he solved only two of the eight problems correctly). However, at the end of the training he was solving the problems quickly, accurately and with almost no mistakes.

When he was subjected to the hindrances (see Figure 3), his results dropped at first, to seven problems out of eight, but when the intensity of the sonic stimuli was increased, he achieved maximum effectiveness: he solved all eight problems. In his conversation with the experimenter, Valery I. declared: "The outside sound has a mild effect on me; I know how to ignore it and pay no attention to it, since I am used to doing my homework with the radio playing. It even helps me to think."

The characterizations presented above are typical of the behavior of the test subjects whom we placed in the first group. The activating and mobilizing effect of the emotion-producing factors comes out clearly in these characterizations. The initial effect of these factors is to disorganize the subjects' activity, but subsequently they act as subdominant factors that promote better work organization and an increase in work productivity.

The data obtained (Figure 2) indicate that these test subjects /125
belong to the category of people who, when properly motivated, increase their work capacity under conditions of stress. Their behavior is marked by a fighting spirit, heightened tonus, minimum expenditure of strength and insignificant fatigue. The majority of them work easily, without constraint and cheerfully and take pleasure in their work.

Analysis of the record sheets for the test subjects of the second group shows that in the overwhelming majority of cases under tense working conditions there is a periodic variation in their mental-activity indicators in relation to the average results of the first

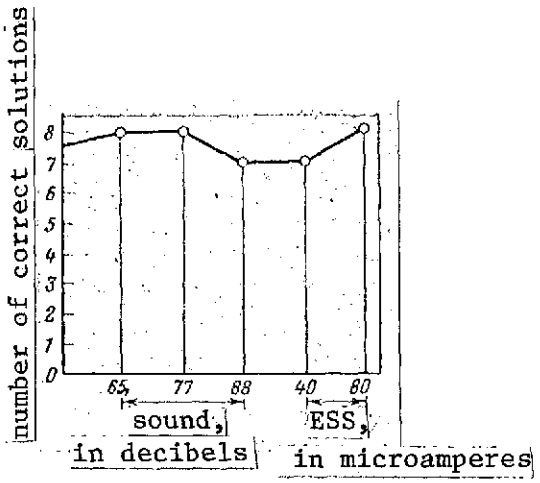


Figure 4. Graph of problem-solving by test subject T.S.

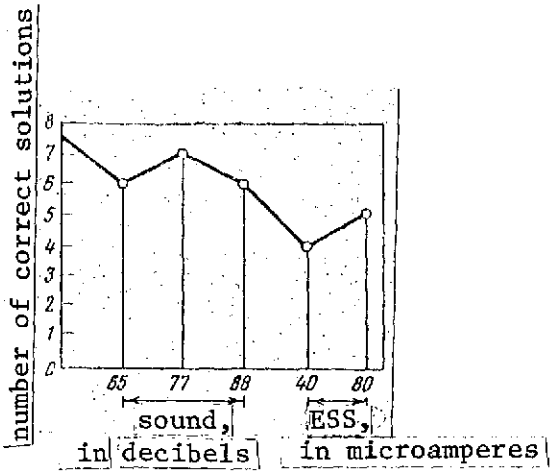


Figure 5. Graph of problem-solving by test subject O.I.

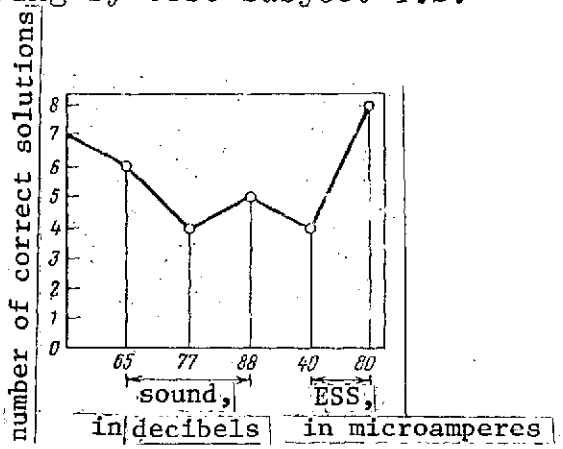


Figure 6. Graph of problem-solving by test subject S.G.

series; a period in which the number of correct answers increases is usually followed by a period in which it decreases. With respect to their amplitude, these variations are roughly equal; therefore, when we added them up and found the arithmetic mean, we obtained results that were not very different from the work-effectiveness indicators obtained at the end of the experimental training. As an example that illustrates this statement, we may cite the record sheets of the /126
studies involving Tat'yana S. This test subject mastered the ability to solve problems involving computations based on the instruments extraordinarily quickly and successfully. From the very beginning of the training she performed the necessary cogitative operations easily. and without any tension. At the end of the first series of experiments the test subject was solving an average of 7.5 problems out of 8. When she was subjected to the sonic stimuli, the number of correct solutions began to vary periodically, as may be seen from the graph (Figure 4). At first the test subject said that the sound did not hinder her work, but from time to time she felt pain in her ears, grimaced and blocked her ears with her fingers; with a maximum effort, she tried to concentrate, to ignore the stimulus that was affecting her and to give as many correct answers as possible. Things became especially difficult for her when she was subjected to a sound with

an intensity of 88 decibels. The test subject declared: "The intense sound has made me tired and I have a headache, but by an effort /127
I will force myself to solve the problems correctly." Tat'yana S. was very afraid of the electric shocks. She asked that the voltage be reduced and she tried as hard as she could not to make mistakes, since that would save her from being subjected to the ESS. In her conversation with the experimenter she said: "It is better to work with the current than with the sound, since the sound is heard all the time, while the shocks come only when I make a mistake, and that makes me mobilize myself and find the correct solution."

We found a similar picture with respect to changes in the effectiveness of mental activity in the case of other members of this group when they were subjected to the hindrances. Thus, test subject Aleksandr M. also noted that the sound made him tired and kept him from concentrating and that he had to mobilize himself and make a considerably greater effort. He began to get pains in his head and ears and got tired quickly because of the intense sound. He was not afraid of the shocks and tried to behave calmly and to pay no attention to the ESS.

Psychological analysis of the nature of the changes in effectiveness and of the statements of the test subjects in the second group gives us grounds for believing that this is a case of struggle between subcortical and cortical dominants. From time to time, the emotional state produced by the hindrances reduces the effectiveness of their mental activity, but by making volitional efforts the test subjects suppress the emotions and make them subdominant, which leads to an increase in the effectiveness of their work. At first an increase in the intensity of the interfering factors has a negative effect on the course of their thinking; however, by concentrating their will, the test subjects again master their emotions, sometimes at the cost of great tension. Thus, a person's emotions and will struggle against one another with varying success, and this is objectively manifested in the variations in the reliability and effectiveness of his mental activity.

We find a more variegated picture with respect to changes in

mental activity in the case of the test subjects of the third group, whose shared attribute is a drop in their mental work capacity when they were subjected to the hindrances.

As was to be expected, analysis and summarization of the experimental data showed that this drop was the result of a whole series of psychological factors, among which an emotional state of fear and dread ranks first. Thus, among the test subjects in this group it is possible to single out six persons who were obviously affected by this factor.

Knowledge of the record sheets of the studies makes it possible for us to give a more detailed description of the behavior of these test subjects and to determine certain psychological regularities that are of interest, in our view.

Test subject Oleg I. is a typical member of this group. During /128
the experimental training he showed himself to be capable and diligent and mastered the work on the apparatus fairly quickly. At the end of the training he was solving the problems correctly, quickly and without visible tension. However, when he was subjected to the hindrances, there was a sharp change in his behavior. Even a relatively soft sound (intensity: 65 decibels) had a strong effect on his success in solving the cogitative problems. An increase in the intensity of the sonic stimulus to 88 decibles made the test subject strain himself excessively, and he complained of being tired. The effect of the ESS was even worse: it disorganized his activity. Oleg was very afraid of the current. Because of this fear of receiving a shock, he recalculated the same problem several times, he was agitated and he made mistakes in solving even the easiest problems. He pressed on the levers very cautiously because of his fear of receiving a shock of the answer was incorrect.

In his conversation with the experimenter, Oleg I. frankly stated that he was thinking all the time about the possibility of a shock and that his fear was so great that he often confused the figures and was unable to read the instruments correctly. After the experimenter explained that the electric current was harmless

and that it was necessary for him to mobilize his will, the test subject calmed down and promised to pull himself together, and this had a positive effect on the results of his cogitative activity, as may be seen from the graph (Figure 5). Thus, when he was subjected to a current of 40 microamperes his productivity fell to 4 solutions, but when the strength of the current was increased to 80 microamperes he gave 5 correct answers.

The natural positive effect of the mobilization of volitional efforts on the effectiveness of a person's cogitative activity was manifested most clearly in the experiments involving test subject Sergei G., who, when he was subjected to the sonic hindrances, began to make mistakes, became flustered and complained of a headache. When he received an electric shock, he cried out in fright and in a trembling voice begged that the voltage be reduced; since he was afraid to make a mistake, he moved the levers indecisively, apprehensively and with a grimace. Naturally, this state led to a considerable drop in the effectiveness of the test subject's mental activity.

However, after he had worked with a current of 40 microamperes, the test subject declared: "Now I know what the current is like. It is unpleasant, but it is not as terrible as I thought before. There is nothing to be afraid of, and I will try to work as well as possible." During the final series of experiments, despite an increase in the strength of the current to 80 microamperes, the test /129 subject was able to mobilize himself and give the maximum possible number of correct solutions (see Figure 6).

The facts presented above indicate that a person also has enormous reserves with respect to imperviousness to hindrances, which can be exploited by overcoming fear and mobilizing the volitional sphere of the personality. Under certain conditions, overcoming fear is a powerful stimulus that increases a person's work capacity. This serves to emphasize the exceptionally important role that cultivation of the operator's volitional qualities may play in increasing the effectiveness and reliability of his work. In continuing our analysis of the data pertaining to the third group of test subjects,

we should deal in greater detail with a relatively small group of test subjects. The productivity of the activity of the members of this group (four persons) fell when they were subjected to the hindrances, because their attention was disrupted; this disruption was manifested in insufficient concentration of attention and in reduced speed in switching and distributing their attention. These test subjects were unable to ignore completely the effect of the outside stimuli. The latter made it impossible for them to concentrate on solving the problems, which in turn led to lapses in their work and to increased nervous-psychic loads.

Yury Ye. is a typical member of this group. The sonic stimuli diverted his attention; he confused the signs, forgot the instruments and made mistakes. Excessive volitional tension was required for him to solve the complex problems; he held his head, grimaced and sighed loudly. The productivity of his activity dropped, and his success curve was marked by sharp fluctuations. In evaluating his state, the test subject said the following: "The outside sounds make it impossible for me to concentrate; therefore, I try to mobilize myself, though I am not always successful. It is especially difficult to work during the intense signals."

Thus, despite all their efforts, in the case of the test subjects in this group there were inevitably fluctuations in their attention, which had a negative effect on the results of their cogitative activity. Their work was slow, involved great psychic tension and led to rapid fatigue and to an increase in the number of errors. For example, while solving the problems of the first series of experiments, Boris A.'s attention was riveted on the instrument panel, he was tense and solved the problems quickly but incorrectly. However, he subsequently mastered the ability to orient himself correctly and to find adequate solutions. The work made him tired, and he was distressed by his mistakes.

During the second series of experiments, the sonic stimuli and /130
the ESS interfered with his concentration and confused him. Boris A. was afraid of the ESS. He said that the outside sounds had an

especially strong effect on him. They disorganized his activity. Because of the emotion-producing factors, the number of his errors rose from 9 in the first series of experiments to 14 in the second, i.e., an increase of 55%.

Comparison of the total data for the work of the test subjects in this group showed that when they were subjected to the emotion-producing factors, there was an average increase of 39% in the number of errors.

Such a drop in the effectiveness of the test subjects' work may be explained by the fact that the dominants produced by the sudden effect of the electric-skin stimulus have great inertia, thanks to which the test subjects were incapacitated for a long time. We find a characteristic example of this effect in the record sheets of the experiments. A test subject made a mistake in solving problem five and received an ESS shock. He was unable to collect his thoughts for a long time; therefore, he made mistakes in solving problems six, seven and eight. The majority of the test subjects complained that their work was hindered by the ESS and the sound, as well as by the yellow and white light.

The results of the conversations with the test subjects made it possible to establish the following curious facts. It turned out that 19 of our test subjects noted that their work was severely hindered by the outside sounds; 12 test subjects noted the negative effect of the light stimuli, and in their opinion the orange and white light had the strongest emotion-producing effect. As for the electric-skin stimulus, 10 test subjects noted that the ESS did not hinder their work. Three of these subjects emphasized that the ESS had a mobilizing effect and helped them to think and to find mistakes.

By comparing the verbal statements of the test subjects with the results of their activity, we came to the conclusion that by no means was there always a drop in the activity indicators of those test subjects who spoke of the hindering effect of one or another emotion-producing factor. Moreover, the overwhelming majority of

TABLE 1.

SUMMARY OF EXPERIMENTAL DATA CONCERNING THE TEST SUBJECTS

No.	Test Subject	Average number of problems solved			Data from subjective statements
		Under experimental training conditions	Subjected to sonic hindrances	Subjected to the ESS	
1.	Ye.F.	7.5	8	7.5	Sound and ESS do not hinder his work
2.	V.G.	6.5	6.3	7	Sound and ESS help him to work
3.	Ye.Yu.	5.5	6	7.5	Sound and ESS do not hinder his work
4.	B.V.	6.5	7.33	7.5	Mild reaction to sound and ESS
5.	L.V.	7.5	7.66	7.5	Sound has no effect, not afraid of ESS
6.	P.T.	7.5	7.66	7.5	Sound is a severe hindrance, afraid of ESS
7.	P.Yu.	7	6.66	7	Sound is a severe hindrance, afraid of ESS
8.	M.A.	7.5	7.33	7	Sound helps him to work, afraid of ESS
9.	B.M.	7.	7.33	8	No reaction to ESS, overcomes the sound
10.	L.A.	7.5	7.33	7	Sound not a hindrance, not afraid of ESS
11.	V.I.	7.5	7.33	7.5	Sound not much of a hindrance, ESS has a mild effect
12.	L.V.	4	4.33	4	Does not notice the sound, ESS has an unpleasant effect
13.	D.V.	7	6.33	7	Sound hinders his work, ESS has a strong effect
14	O.I.	7.5	6.33	4.5	Sound and ESS have a strong influence
15.	K.B.	7	4.33	6	Sound not a hindrance, afraid of ESS
16.	Ts.G.	8	7	7	Sound a mild hindrance, ESS has an unpleasant effect
17.	G.S.	7	5	6	Sound hinders his work, ESS has a mild effect
18.	Yu.Ye.	7	5.66	6.5	Sound has a strong effect, ESS a mild effect
19.	Z.A.	7.5	4	6	Sound has a strong influence, ESS a mild influence
20.	A.M.	7	5.66	6.5	Sound was an irritant, afraid of ESS
21.	Kh.Ya.	8	6	7	Sound an irritant, ESS has a strong effect
22.	M.S.	7	6.66	5.5	Gets tired of sound, ESS has a mild effect
23.	N.S.	8	7	7	Sound has mild influence, and ESS as well
24.	M.A.	7	6.33	6.5	Sound hinders his work, afraid of ESS
25.	F.M.	7.5	7	7	Sound and ESS have a mild effect
26.	B.A.	7	6.66	7.5	Sound hinders his work, afraid of ESS
27.	P.T.	7.5	7.66	7.5	Sound hinders his work, afraid of ESS
28.	T.S.	7.	5.66	5	Sound hinders his work, afraid of ESS
29.	S.G.	7	5.66	5	Sound hinders his work, afraid of ESS

TABLE 1. (continued)

No.	Test	Average number of problems solved			Data from subjective statements
		Under experimental training conditions	Subjected to sonic hindrances	Subjected to the ESS	
30.	K.A.	7	6.33	4.5	Gets tired of sound, ESS has a strong effect
31.	S.D.	7.5	6.33	6.5	Sound has a strong effect, ESS a mild effect
32.	V.V.	5.5	5.66	4	Sound and ESS have a mild effect
33.	N.V.	5.5	6.66	4.5	Sound has a strong effect, ESS has a mild effect

the test subjects whose work indicators improved when they were subjected to the emotion-producing factors noted that the sonic, light and electric-skin stimuli had a strong effect on them. However, they gradually adapted to extreme working conditions, and after that they solved the problems far more successfully and reduced the number of their errors considerably.

Emotional tension was also clearly manifested in the work of /132
those test subjects who tried by many means possible to hide their distress from the experimenter, since they saw in it a manifestation of weakness and inferiority. For example, Sergei D. tried to appear calm and cool. He said that he was not afraid of the current, but when he was unsure of the correctness of his solution, he tried to avoid punishment by procrastinating and moving the levers cautiously, and he reacted extraordinarily impulsively to the shocks.

When he was subjected to the sonic hindrances, Sergei D. made gross errors, became tired quickly, felt nervous and lost his capacity to work. In this connection, it is necessary to compare the data from the subjective statements of our test subjects with the objective indicators of their work.

Comparison of the test subjects' subjective assessments with the objective indicators of their work indicates that the test subjects' subjective statements do not always coincide and sometimes conflict with the objective indicators of their work. There were instances in which a test subject believed that the outside sounds did not hinder his wrok, but when he was subjected to hindrances of this kind the number of correct answers fell. Or a test subject could not stand the ESS and was afraid of it, but when he was subjected to it his mental-activity indicators improved considerably.

Summarization of the data presented in Table 2 makes it possible /133
to give the following quantitative characterizations of the interconnection between the experimental data obtained by objective means and the experimental data obtained by subjective means.

The subjective assessments and the objective data coincide completely in the case of 16 test subjects, who make up 50% of the total, partially coincide in 3 cases (9.4%) and contradict one another in the case of 13 test subjects (40.6%).

The experimental data that have been presented give us grounds for believing that all of our test subjects were subject to emotional states to one extent or another. However, in those cases in which the subjects, thanks to volitional efforts, succeeded in mastering their emotions, the latter became subdominant and helped to improve the subject's basic activity. On the other hand, the domination of uncontrolled emotions has a negative (up to and including complete disorganization) effect on the performance of operator functions under tense working conditions.

The results of the experimental studies that we have done not only confirm the hypothesis that we advanced to the effect that a person's emotional behavior is governed by the regularities of dominant relationships, but also make it possible to draw the following important practical conclusion about increasing the operator's reliability.

When interpreting emotion as a dominant unconditioned-reflex mobilization of the organism's internal powers aimed at satisfying an actualizing organic need, we should first of all keep in mind the positive role that it can play in any kind of work, provided that it is voluntarily controlled. Therefore, efforts to increase the reliability of a perosn's work should not take the path of suppressing and inhibiting emotions, but rather should have as their aim arming the person with the ability consciously and voluntarily to control his emotional behavior, using emotions as an effective means of increasing the reliability and effectiveness of his work.

Continuing our discussion of the experimental data presented above, we should note first of all that they are in close accord with and to a great extent confirm the hypothesis advanced by Ye.A. Mileryan [1] concerning the existence of the following basic types

TABLE 2.

INDICATORS OF THE RELIABILITY OF THE PERFORMANCE BY THE TEST SUBJECTS OF THE SENSOMOTOR AND INTELLECTUAL FUNCTIONS UNDER EXTREME WORKING CONDITIONS

Description of the activity	Per cent of test subjects who improved their work indicators under conditions of stress	Per cent of test subjects with stable work capacity	Per cent of test subjects with lower reliability indicators under extreme working conditions
Sensomotor control functions	29	41	30
Problem-solving with the instruments	15.6	18.8	65.6

of behavior under extreme working conditions.

The most common type of behavior is the "tense" type, which is characterized by considerable fluctuations in the work-capacity indicators, increased tension, constraint and impulsiveness in the test subjects' performance of their functions. The performance of these functions involves great nervous-psychic expenditures, which in a number of cases lead to a drop in effectiveness, reliability and work capacity. /134

The second type of emotional behavior, the "cowardly" type, is manifested in the worker's deliberately evading the performance of his assigned functions under difficult conditions and in his striving to keep himself from becoming involved in the course of events.

The third type of behavior, the "inhibited" type, is manifested in complete inhibition of the worker's actions, which is usually brought about by strong emotion-producing factors.

The most graphic and dangerous form of the manifestation of a person's emotional instability is effective disruptions of his activity, as a result of which he begins to act aggressively, senselessly and in an uncontrolled manner, thereby worsening the state of the system that he is controlling and bringing on catastrophes and emer-

gencies more quickly. This is the aggressive-uncontrolled type of behavior.

A comparative analysis of the distribution of our test subjects with respect to their success in performing intellectual operations while being subjected to stress-factors, and the results obtained earlier during the experimental study of changes in sensomotor coordination under conditions of stress, shows that the intellectual elements of operator activity are less reliable, i.e., more subject to being affected by stress-factors, than the sensomotor elements of operator activity.

Thus, in the tests of the reliability of the operator's performance of the sensomotor functions, 29% of the test subjects had higher work indicators under conditions of stress, but the corresponding figure for the experiments involving the solution of cogitative problems was 15.6%. /135

Forty-one per cent of the test subjects showed stability in their performance of the sensomotor functions, whereas only 18.8% showed stability in solving the cogitative problems when subjected to the hindrances.

When one compares the percentages of the test subjects who had lower indicators under tense working conditions, one can easily see that in the case of sensomotor coordination this group accounted for about 30% of the subjects, whereas in the case of the performance of the intellecutal operations it accounted for 65.6%.

What has been said indicates that the reliability of work involving the performance of intellectual functions under conditions in which the operator is subjected to hindrances drops by more than 35%. This figure indicates that it is necessary to pay special attention to optimizing the conditions under which the operator performs the intellectual functions assigned to him.

At the same time, the data obtained also indicated that the per-

formance of these functions makes increased demands on the emotional-volitional sphere of the personality. That is why, in order to resolve scientifically the questions involved in optimizing and increasing the reliability of the operator's work, we should formulate a theoretical concept that explains the nature of the regularity governing the appearance of emotions and their interconnection with feelings, will, and other psychic phenomena, and why we should also determine precisely the role of emotional states in man's work activity.

Proceeding from the working hypothesis advanced by Ye.A. Mileryan in the preceding work [2] concerning the psychological nature of man's emotional states, we should view emotions, feelings and will as a single psychic process, whose material substratum is the interaction of the dominants that appear at the different levels of the nervous system.

Basal mobilizing forms of personality activity are manifested in emotions; the organizational, volitional and motivational components of the personality's psychic activity are built on these forms. Feelings and will, whose appearance is based on emotions and which develop thanks to emotions, serve as the means for the conscious regulation of behavior and for a person's control of his emotional state. In light of this hypothesis, it has proved to be possible to explain /136
the types of human behavior under conditions of stress that have been described above, as well as to map out, in this connection, specific ways of optimizing the operator's working conditions and increasing his work capacity under extreme working conditions.

Thus, the "tense" type of behavior under conditions of stress is characterized by increased tension, by constraint and impulsiveness in the operator's performance of his functions, which are manifested in convulsive squeezing of the control levers and in excessively abrupt and impulsive performance of work actions, by riveting of attention on the objects being tracked, by considerable fluctuations in work capacity, etc. Proceeding from the theoretical propositions set forth above, this type of behavior may be interpreted as the result of a struggle between the subcortical (emotion-producing)

dominants and the cortical dominants connected with volitional efforts. It may be assumed that this involves an unbalanced state in the emotional-volitional sphere of the personality; under difficult working conditions, the emotional components of psychic activity gain the upper hand at times and the volitional components gain the upper hand at other times. Performance of this psychic activity involves excessive nervous-psychic expenditures and rapid fatigue.

Studies of emotional stability in the operator's work have shown that in the case of most people, tension may be eliminated by having them develop dynamic stereotypes and make them automatic during a specially organized training period aimed at forming skills. Work activity at the level of a skill takes on the qualities of stability, reliability and imperviousness to hindrances. In our opinion, the reason for this is that an activity that has become automatic does not require that attention be paid to it, and it can be carried out in areas of the brain located outside a dominant.

The existence of the "cowardly" type of emotional behavior may obviously be explained by the domination of the instinct of self-preservation. The activity produced by the emotion-producing factors is characterized by the fact that under difficult working conditions the operator feels afraid, attempts to procrastinate and tries to move a little further away from the control panel, so as to be free of the effect of the stress-factors. As is shown by the data from the studies done by Ye.A. Mileryan, this type of behavior can be changed and improved by certain upbringing influences that help the person to overcome the emotions of fear, to emerge the victor from a difficult situation, to strengthen his faith in himself and in his potentialities and to develop in him the necessary volitional qualities. In those cases in which these efforts are successful, there /137 is a considerable rise in the stability and productivity of activity performed under extreme conditions.

The representatives of the "inhibited" type of behavior are considerably more difficult to rehabilitate, since here we are dealing with protective inhibition produced by an extraordinarily strong sub-

cortical dominant that paralyzes the person's will; the mechanism of the reflex of natural caution goes into operation, and this makes it impossible for the operator to take any action.

At the present level of development of our psychological knowledge, we can only recommend that inhibited operators be weeded out by means of psychological selection. The same "corrective" measure may be resorted to in the case of the representatives of the aggressive-uncontrolled type, whose behavior is characterized by effective disruptions of activity under conditions of stress, which are the result of the uncontrolled and completely unchecked domination of unconditioned-reflex aggression dominants. We do not yet possess effective means of psychologically influencing such people. Weeding them out promptly is the best way to increase the reliability of the operation of a systems-technology complex.

The most promising category in this respect is made up of those people who improve their work indicators considerably under conditions of stress. It may be assumed that in their case second-signal dominants not only neutralize the effect of the emotion-producing factors, but also utilize them, i.e., are fed by the subcortical subdominants; therefore, the behavior of these people is characterized by a fighting spirit, increased work capacity, minimum expenditure of strength and insignificant fatigue.

It is natural to assume that in selecting those to be admitted to educational institutions that train operators for especially responsible vocations, top priority should be given to representatives of the progressive type of behavior.

Thus, psychological selection of individuals to perform operator functions is an important means of increasing the reliability of the operator's work and optimizing his working conditions.

The experience that we have acquired in developing methods for studying the operator's work under conditions of stress gives us grounds for believing that it is possible to use the simulation

methods of studying operator thinking described in this work for the purpose of testing the vocational fitness of candidates for admission to vocational-technical schools.

REFERENCES

1. See Ye.A. Mileryan's article "Emotional-Volitional Components of Operator Reliability" in this collection.

2. See Ye.A. Mileryan's article "Emotional-Volitional Components of Operator Reliability" in this collection.

N75 17951

THE OPERATOR'S EMOTIONAL STABILITY

P.B. Zil'berman*

Scientific and technical progress has given birth to a number of new vocations, and above all it has made into a mass vocation the vocation of operator, which is taken to mean a specialist who controls automatic processes.

The operator is usually regarded as an element of a semiautomated system. In this regard, man is not a simple element of the system, but an integral component, the most important one of the system.

A top-priority task of engineering psychology is to coordinate the functions of automatic devices with the operator's activity.

Analysis of the operator's activity that is contained in the works of a number of psychologists [1] makes it possible to state that the basic content of the new aspect that distinguishes the operator's work from other worker vocations consists in the maximum decreese in the load of the motor portion of work actions and in the unusually heightened role of the functions of the intellectual and emotional-volitional components.

Behind the apparent simplicity of the operator's sensomotor action is often hidden a very great nervous load connected with his great responsibility, which grows along with the complexity of the system. K.M. Gurevich and V.F. Matveyev emphasize that simplification of the structure of an action is accompanied by an increase in its effectiveness, so that "pressing a button" may insure that production proceeds normally or may lead to the destruction of considerable material values and place people's lives in jeopardy [2]. /139

*Kiev, Ukraine Republic Institute of Psychology

Thus, while technical progress frees man from heavy physical labor, at the same time it makes great demands on the intellectual and emotional spheres of his personality and on the reliability of the operator's work.

Researchers who deal with questions of operator reliability regard it as a certain overall quality that encompasses various aspects of personality behavior. Among the factors that determine the reliability of this behavior, a significant role belongs to emotional stability.

1. Posing the Question. Defining the Concept "Emotional Stability"

Despite the fact that the problem of emotional stability is of great practical interest for practical work, which is indicated by numerous statements by leading Soviet psychologists — A.N. Leont'yev, B.G. Anan'yev, B.F. Lomov, K.K. Platonov, F.D. Gorbov and others, it still remains true that not very much work has been done on this problem. This is indicated by the small number of research projects that have been devoted directly to the study of emotional stability. There are only the works of K.K. Platonov and L.M. Rozet, V.L. Marishchuk, Ye.A. Mileryan and A.V. Solodkova, V.V. Suvorova, I.T. Romanyuk and O.A. Chernikova. A considerably greater number of works touch indirectly on questions connected with the problem of emotional stability. Among these are the works of a large group of psychologists from Moscow University headed by A.N. Leont'yev, who are engaged in research on the state of tension (O.V. Ovchinnikova, N.I. Nayenko, I.Ya. Leonova, V.F. Reutova, G.V. Rodionova and others). The same applies to the works of V.M. Pisarenko, Yu.A. Kiselev, A.Ts. Puni and a number of other authors.

Research on the role of the "human factor" in automated systems /140 is drawing the attention of scientists more and more to the emotional complex of the operator's subjective experiences, since the specific nature of his activity involves great nervous-emotional loads. A feeling of responsibility and an awareness of the possible consequences

of a mistake are strong emotion-producing factors that produce tension in the operator's work.

How does one or another individual behave under extreme conditions, how do emotions affect operator activity, what are the ways of increasing a person's psychic stability in an emotive situation — this is by no means a complete list of the questions whose resolution is the aim of research on emotional stability.

Unfortunately, works aimed at studying emotional stability are most often empirical in nature. We do not find in these works a proper substantiation of the concept of emotional stability. Furthermore, different authors adhere to different interpretations of the term "emotional stability."

A number of psychologists used this term as if it were self-explanatory. In certain works devoted to the study of operator states and reliability, the authors (V.D. Nebylitsin, K.M. Gurevich and certain others) avoid using this term, apparently because of a feeling of natural cautiousness and scientific conscientiousness. The lack of an adequate theoretical substantiation of the meaning of emotional stability based on the Marxist-Leninist doctrine concerning the personality means that the methods used in studying this quality are also inadequate. These facts indicate the need to examine in greater detail what should be understood by emotional stability. A review of modern psychological literature, both domestic and foreign, indicates that emotions and feelings are very important both for the organism's vital activity and for the social forms of human behavior and activity. V.I. Lenin's brilliant idea concerning the importance of "human emotions" in seeking out the truth is the most graphic confirmation of this. K. Marx pointed out the enormous importance of the strength of the passionate emotional component in human activity. He emphasized that a passion is an essential force of a person that is vigorously striving for its object. The French /141
Enlightenment thinkers pointed out the positive role of emotions and feelings, and the Russian revolutionary democrats adhered to this point of view. A.M. Gor'ky made a remarkable statement about the

role of emotions and feelings in their relationship with reason: "Man's development has gone awry for some time now - our mind is developing and our feelings are being ignored. I think that this is harmful to us. Intellect and instinct must merge into a well-ordered harmony, and then, it seems to me, all of us and everything that surrounds us will be more vivid, brighter and more joyful. I believe that this is possible!" [3,4].

It is true that these statements deal with the higher, purely human emotions - with feelings and passions, but feelings and passions are manifested through emotions and are actualized in them (A.G. Kovalev [5]). Consequently, what is said about feelings is to a considerable extent also relevant to emotions. But even if we view emotions themselves in the narrow sense of the word (fear, joy, anger, etc.), their enormous biological and social value is still obvious. D. Lindsley demonstrates their activating role; P.K. Anokhin has convincingly shown their evaluative significance; K.K. Platonov states that emotions are one of the means of reflections; and P.V. Simonov sees the role and importance of emotions in the fact that they act as a compensatory mechanism when there is insufficient pragmatic information. In his latest works P.V. Simonov shows that emotional excitation plays an activating role in the so-called mechanism of psychic mutagenesis [6].

All of this convinces us that emotions are expedient and necessary in vital activity. We must not lose sight of this conclusion when discussing emotional stability. Above all, it is necessary to focus our attention on the positive role of emotions and feelings. Emotions appeared in the early stages of the appearance of the psyche, on the basis of the organism's first-signal relations with the environment. Emotions appeared initially as unconditioned-reflex reactions to vitally important signals. Their role lay chiefly in insuring adaptive behavior. The biological adaptive function of emotions has not lost its importance even in the higher stages of the development of the psyche, up to and including man, but, as is known, the relationships between this form of behavior and the rational behavior of the social personality are complex and contradictory. /142

This is precisely why in certain cases emotions may act as a factor that objectively hinders the adequate performance of activity in a given concrete situation.

While we continue to acknowledge the harmony between reason and feelings, we cannot fail to see a certain antogonism between these processes. Long ago Spinoza dealt with this feature of man's emotional-rational life. He pointed out the dual role of emotions, defining them as states that "increase or decrease the body's capacity for action, that favor this capacity or restrict it...[7]" In I.P. Pavlov's works [8] we find an attempt at a physiological substantiation of the antagonism between the emotional-feeling and the rational. The fact that in an affected state a person "says and does what he does not allow himself to say and do when he is in a calm state, and what he bitterly regrets when the effect passes" is explained by Pavlov in terms of excitations that come from the subcortex and overcome higher inhibition. In his article "A Physiologist's Answer to the Psychologists," I.P. Pavlov shows the physiological mechanism of "so-called blinding due to the effect of passion." Analyzing V. Keller's well-known experiment, [9] in which a dog, when he sees meat that is lying far away from the bars, runs out through a side door and gets it, but the same piece of meat placed right in front of the bars, leads to inexpedient behavior (the dog stamps his feet near the bars, yelps, tries to get the meat through the bars and does not go outside them), I.P. Pavlov explains this case in terms of strong excitation produced by the piece of meat lying nearby in the olfactory and visual centers of the hemispheres, which, in accordance with the laws of negative induction, inhibit the remaining areas of the hemispheres. Pavlov says that his experiment reproduces the mechanisms of strong mental concentration and emotional blinding. Works dealing with engineering psychology, sports psychology, etc. contain numerous instances that show that emotional tension is capable of disorganizing activity under certain conditions.

Thus, on the one hand, emotions are a necessary component of /143
vital activity, and from this standpoint the concept of emotional stability appears odious to a certain extent, but on the other hand

this concept has a legitimate right to exist, since emotional excitation in certain relationships acts as a factor that disorganizes activity.

The dialectic of emotional experiences in their relation to activity lies in the dual nature of human emotions. Emotions that carry out primary reflection at the level of instinctive activity serve the organism in its biological definiteness. In this respect they are unquestionably expedient and significant, since they enable organisms to adapt better and to survive in complicated situations in a constantly changing environment. The biological expediency of emotions, and of the emotions of flight in particular, has been demonstrated by all authors. Every one of the modern theories concerning emotions finds in them an unusually useful adaptive quality. In this regard, the various adaptive qualities that have been found by the different theories of emotions apparently do not contradict, but supplement one another. We can and should accept the fact that emotions play the role of activators of psychic and physiological processes. We cannot fail to see the fact that during an emotional reaction humoral mechanisms begin functioning and substances enter the blood that promote the mobilization of the additional energy resources needed to overcome obstacles, etc.

A large number of functions performed by emotions further emphasizes their role as an integrator of the central mechanism of psychic regulation at the lower levels of the development of the psyche. One may say with certainty that even at the higher levels of the development of the psyche, when the large hemispheres of the cerebrum are fairly well-developed, emotions continue to perform the role of one of the central integrators of animal behavior. Many authors agree that emotions are the precursors of consciousness. Thus, D.N. Uznadze [10] writes that "... emotion...is the first stage in the development of consciousness...It is the most primitive form of consciousness." With the appearance of consciousness, the functions of emotions examined above were not eliminated, but there is no doubt that they did not remain unchanged. Above all, their role in the individual's behavior changed. Rational behavior condi- /144

tioned by the social experience amassed in the process of historical development assumed the top-ranking position. Emotions seemingly receded into the background, but in difficult situations, when reason does not suggest the correct solution immediately, the individual's actions may follow a scheme determined by age-old emotional reaction. Behavior ensures that is characterized by tension, affect, frustration, confusion and similar states. Consequently, the appearance of one or another state may be regarded as the result of the interaction of different levels of behavior regulation. In this connection, emotional stability or instability may be interpreted as an indicator of the relationship between emotional and rational reactions in a situation folled with emotion-producing factors. There is no need to demonstrate that no matter what personality characteristic we examine, the study will prove to be incomplete if analysis does not go hand in hand with synthesis of the integral personality in its diverse relationships and connections with the surrounding world.

At the present time psychologists use two terms that sound very much alike: "Emotional stability" and "stability of emotions." Their apparent similarity often obscures the fundamental difference between the concepts that they express.

Stability of emotions denotes a certain constancy of an emotional feeling that has appeared, primarily stability of the sign of the emotion that is felt. This term denotes a qualitative feature of the personality's emotional feeling, a feature consisting, on the one hand, in a certain tendency to maintain the state of a certain emotional feeling for a more or less prolonged period, and on the other hand, in the personality being predisposed to a certain extent to feel primarily emotions of a certain sign.

So-called stability of emotions is not the same as the content of the concept that is expressed by the term "emotional stability."

The linguistic similarity of these terms has led to certain authors interpreting the meaning of emotional stability if not as stability of emotions, then at least in a way that is very close to

the meaning of this term. This tendency is rather clearly manifested /145 in the works of O.A. Chernikova, who uses the term "emotional stability" to mean a certain stability in the level of intensity and in the qualitative features of an emotional feeling. [11].

V.G. Norakidze [12] writes about emotional instability in the sense of frequent alternation of emotions of opposite signs in the case of certain psychic illnesses. Apparently, a similar viewpoint is taken by N.D. Levitov [13], who connects emotional instability with instability of moods and emotions as a consequence of instability of feelings, susceptibility to imitation, etc.

However, there is also another tendency, which consists in treating emotional stability as stability of the psychic and motor components of activity in an emotive situation. This is the viewpoint of the majority of the researchers who deal with questions of emotional stability (K.I. Platonov, T.T. Dzhamgarov, V.L. Marishchuk, YeA. Mileryan and others). The authors who adhere to this conception use the concept "emotional stability" as a certain indicator of the personality's psychic stability when it is subjected to emotion-producing factors. It is noteworthy that in this approach we are dealing with neither stability of emotions nor stability of emotional states, but rather with functional stability that is the result of the personality's capacity to resist and combat the emotional stimuli and already existing emotional states that might have a negative effect on the progress of activity. Apparently, it would be more precise to express so-called emotional stability by the terms "emotional endurance" for a state that lasts for a relatively long time and "emotional staying power" in the case of emotion-producing stimuli that are at work only briefly. However, the imprecision of the term should not obscure and still less change the meaning of the concept that it represents. After all, the essence of the matter lies not in the works, but in understanding the essence of what should be meant by these words.

In contrast to O.A. Chernikova, who defines emotional stability as "stability of the qualitative features of emotional states...,"

this approach regards it as a characteristic of the personality, with which one has to agree if one does not wish to deprive the concept "emotional stability" of its meaning and independent significance. /146

Indeed, what new content can there be in the expression "a state of emotional stability," as compared to, let us say, the state that A.Ts. Puni [14] has called "a state of combat readiness?" On the other hand, a "state of emotional instability" is nothing but a state of affect, tension, stress, etc.

A different picture emerges when we examine emotional stability. This term reflects a certain synthetic quality of the personality that characterizes the dynamic relationships among the individual's emotional-volitional, intellectual, motivational and nervous-humoral processes in connection with the emotional character of the situation in which the activity is performed. This concept takes on its own independent significance, which stems from the need to study the dynamics of the interprocess relationships that exist in the psyche of a specific personality.

In the experiments that we have done, we have often observed that when many emotionally excitable test subjects who have a difficult time dealing with an emotion-producing stimulus were influenced by the appropriate motivational directions, their activity indicators not only did not drop, but they actually achieved higher results than when they were working without the emotion-producing stimulus. This indicates the complex dynamics between the emotional and volitional components of activity. It is appropriate to use the term "emotional stability" to denote precisely this trait, which is a feature of the personality's moral-volitional qualities that consists in the possibility of resisting emotional states that disorganize behavior.

In our view, this viewpoint explains the very origin of the concept "emotional stability," which necessarily appeared when a term was needed to express the synthesis of the interaction of emotions, will and intellect in their relation to activity, when it became obvious that the functionalism that was current in psychological research

no longer had anything to offer.

It seems to us that placing emphasis on this question is of fundamental importance not only for overcoming the confusion and lack of clarity in the definition of emotional stability, because of which, as we have mentioned, a number of psychologists have aboided this concept, but also, and this is especially important, for correctly determining the meaning of emotional stability, which will make it possible to arrive at an adequate method for studying it. /147

Proceeding from the fact that "stability" should denote "the unchanging nature, identity, constancey of the basic distinguishing attributes of any process," [15] it is necessary to determine the attributes whose constancy we should be talking about when we are dealing with emotional stability.

This is a rather difficult question concerning which there is not yet complete agreement even among the representative of the second conception that we have outlined.

The considerations advanced by K.K. Platonov back in 1943 in his work "Essays in Psychology for Pilots," which was written jointly with L.M. Shvarts, should be considered fundamental. In this work K.K. Platonov examines emotional stability in connection with the level of excitability or emotional lability. At the same time, he points out that "... what is decisive is not high or low emotional excitability by itself, but rather its greater or lesser negative effect on a person's skills and activity [16]."

Unfortunately, neither in this nor in subsequent works does K.K. Platonov give a concrete definition of emotional stability. However, analysis of his reasoning mades it possible to draw the conclusion that emotional stability should be taken to mean what we have set forth above. Thus, in the "Essays" we read the following: "The first type of people, who are easily excitable with respect to their emotions and tend to change their emotional states frequently,

are called emotionally labile (unstable) or relatively more excitable. The opposite type of people, in its extreme form, is called emotionally inert, or relatively less excitable." If the term "unstable" that K.K. Platonov has placed in parentheses is taken to mean emotionally unstable (and judging by the context, this is apparently correct), then an emotionally unstable person is one who: a) is relatively more excitable and b) tends to change his emotional states frequently. Obviously, the second attribute is a consequence of the first. This suggests the conclusion that a personality with opposite data, i.e., with relatively low excitability, should be considered emotionally stable. But this conclusion may lead to a situation in which emotional stability, at least in its extreme manifestations, must be regarded as a negative personal quality. Indeed, who would claim that a person who is incapable of reacting adequately to an emotional situation, a person who shows no emotion during his first flight, his first spin, etc., a person to whom, in the words of an aircraft designer cited by K.K. Platonov, "it makes no difference whether he is flying in a plane or tending geese," is a positive individual who should be trusted to perform a responsible assignment. /148

It is obvious that emotional stability, if it is understood as a positive characteristic of the personality, should be derived from other indicators that are not connected only with low emotional stability, if it is understood as a positive characteristic of the personality, should be derived from other indicators that are not connected only with low emotional excitability and emotional inertness, although the latter are unquestionably significant and cannot be totally ignored. A person of whom K.K. Platonov writes in the same work as a certain "average, most positive type - emotionally balanced" [17] would correspond most closely to the criterion of emotional excitability - emotional stability.

The idea that emotional stability should be viewed more broadly than as a concept of the level of emotional excitability is contained in the statement by K.K. Platonov that has been cited, to the effect that "what is decisive is not high or low emotional exci-

tability by itself, but rather its greater or lesser negative effect on a person's skills and activity"[18]. In subsequent works K.K. Platonov [19] develops this idea: emotional stability is regarded as the interaction of the emotional-volitional qualities of the personality in their relation to the character of the activity, as emotional-motor, emotional-sensory and emotional-mental stability.

This approach makes it possible to treat emotional stability as stability of the motor, sensory and mental components of activity performed when an emotional feeling has appeared. K.K. Platonov points out directly in "Problems of Labor Psychology" that the /149
level of emotional excitability is not the same as emotional stability. He writes: "Emotionally excitable personalities are sometimes nevertheless also stable in the emotional-motor sphere, and vice versa."

The fact that emotional stability must not be understood simply as a lack of lability and of relatively higher excitability is indirectly indicated by the work of A.P. Yershova, [20] who uses the level of emotional reactivity to determine the capacity for being an actor. Not without reason, she regards emotional reactivity as a component of the capacity for performing the work of an actor. An experiment revealed a positive correlation between the level of emotional reactivity and the capacity for creatively embodying in an image the person being portrayed and reproducing his feelings and reactions to his environment. On this basis, all talented actors should be considered emotionally unstable, since one of the components of their ability and talent is relatively higher emotional excitability. There is scarcely any need to demonstrate that this is not the case. It is quite correct to believe that emotional excitability is a vocationally important positive quality of an actor, but the presence of this capacity still does not give one the right to connect the performer's talent with emotional instability. A person who has been properly brought up has a rather large set of chiefly social regulatory mechanisms that insure his emotional stability even when his emotional reactivity is relatively high.

What has been said indicates that emotional stability should

be understood as something more than merely the level of emotional excitability. Attempts have been made in the works of T.T. Dzhamgarov, V.L. Marishchuk, K.K. Platonov, Ye.A. Pletnetsky and Ye.A. Mileryan [21] to present a concrete definition of emotional stability as a characteristic of the personality. /150

Thus, V.L. Marishchuk regards emotional stability "... as the capacity to overcome a state of excessive emotional excitation when performing complex motor activity"[22]. Ye.A. Mileryan defines emotional stability somewhat more broadly. "This characteristic," he writes, "is understood, on the one hand, as nonsusceptibility to emotion-producing factors that have a negative effect on the individual's psychic state, and, on the other hand, as the capacity to control, restrain and manage the emotions that appear, thereby insuring successful performance of the necessary actions [23]."

Above all, these definitions capture the very essence of the phenomenon. However, we must point out certain less fundamental but still important shortcomings of these definitions.

We see a shortcoming in V.L. Marishchuk's formulation in the fact that he speaks of emotional excitation without indicating the content of the emotional state that appears. If this definition were not made more precise, one might think that rather strong emotional excitation is always a hindrance to activity. The preceding analysis indicates that this is not entirely true. What matters is not the emotional excitation, which cannot be insufficient or excessive in and of itself. It can be insufficient or excessive only insofar as it is connected with the substantive side of an emotional feeling. There are, of course, cases in which positive emotions also become hindrances when they reach a certain strength. For example, great joy because of a temporary success that has been achieved may lead to weakening, to a loss of vigilance, to an underestimation of the situation, etc. But in this case as well what matters most of all is not the intensity of the feeling, but the fact that it is inadequate with respect to the content of the situation that has arisen.

Another imprecise aspect of this definition consists in the fact that the author, in viewing emotional stability as overcoming excessive emotional excitation, thereby overlooks the dynamics of the development of an emotional feeling, despite his apparent desire to avoid this. The point is that the final act of overcoming is preceded by a complex structure of development of the emotive /151
state, which proceeds under the control of consciousness and in multilevel interaction with volitional and intellectual processes. When we speak of emotional stability, we should speak not so much of overcoming a negative emotional state that has already appeared as of the capacity for controlling and restraining the development of an asthenic feeling, as is stated in Ye.A. Mileryan's definition. It is rather well known that it is easier to prevent an affective state and to keep it from developing that it is to overcome an unfavorable emotional state that has already gripped the personality and reached its culmination. However, this certainly does not mean that the expression "overcoming an emotional state" cannot be used in condensed formulations, when, for example, one is giving a working definition of the concept "emotional stability."

The definition of emotional stability given by Ye.A. Mileryan is more precise, since it regards this quality, in conformity with the dyanmics of the process of the development of an emotional state, as the capacity for controlling, restraining and managing a developing emotion. As for the first part of the definition, in which emotional stability is interpreted as "nonsusceptibility to emotion-producing factors that have a negative effect on the individual's psychic state," certain clarifications are necessary: first, as we have had a chance to see, nonsusceptibility to emotion-producing stimuli is by no means a positive characteristic of the personality; second, as Ye.A. Mileryan emphasizes, nonsusceptibility to emotion-producing factors "... is relatively rare and therefore cannot be regarded as a mandatory characteristic for every operator.[24]"

Apparently, there is no such thing as absolute nonsusceptibility. We may speak only of relatively lower emotiveness as a characterological trait of the personality. But relatively lower emotiveness is not the decisive factor in determining emotional stabi-

lity. Third and last, nonsusceptibility only to emotion-producing factors that may have a negative effect on the individual's psychic state is apparently conceived as a certain selective nonsusceptibility. /152 The result is as if the same personality may be capable of perceiving a positive emotion-producing stimulus and of reacting to it while being unable to perceive negative stimuli. It is probably that such a capacity of selective reaction is extremely hypothetical and cannot be established without adequate experimental proof.

Comparison and analysis of the different points of view, approaches and definitions of emotional stability make it possible to conclude that emotional stability should be taken to mean an integrative characteristic of the personality that is characterized by an interaction of the emotional, volitional, intellectual and motivational components of the individual's psychic activity that insures the optimum successful achievement of the goal of activity in a complex emotive situation.

This definition, like any other, is unquestionably not the last word, but in our view it is free of the shortcomings peculiar to the characterizations of this concept that we have examined above. This is demonstrated by the fact that in this definition, first, the concept "emotional stability" find its object and its place without coming into conflict with the basic approach to emotions as an expedient psychic process. Second, in complete accord with many authors, emotional stability is regarded as a synthethic, integrative characteristic of the personality that reflects the dialectical unity of the personality's motivation and emotional-volitional and intellectual qualities. Third, this definition overcomes the limitations of treating emotional stability simply as the characteristic of unexcitability or relatively lower excitability, which depends primarily on the mobility, strength and equilibrium of the basic nervous processes. The limited nature of this approach makes it impossible to see the specifically human features of emotional reactions and the dynamics of the interaction of the social and biological components of the personality. Fourth, emotional stability understood in this way, as reflecting specific personal qualities, makes it

possible to assess it at different levels of intensity of emotional feeling. This is important in that activity is accompanied by emotions even when it proceeds under conditions that are by no means extreme.

Last, this approach makes it possible to do fruitful research on the personality during activity under extreme conditions. Instead of measuring the physiological changes appearing in the organism, which indicate changes in the organism's physical state and say very little about the person's psychic feeling, which depends chiefly on social-personal factors, it becomes possible to use the results of the activity to judge the degree of development of those psychic qualities that enable the personality to maintain its work capacity and to voluntarily control and regulate its behavior, even when subjected to extremely difficult and tense working conditions. /153

2. The Method Used in Studying Emotional Stability

We used an instrument designed by Ye.A. Mileryan [25] to study emotional stability, in the sense in which this quality of the personality has been defined above.

The basic factor that distinguishes this method from other methods used to study this quality is that the measurement of emotional stability is based on those changes in the objective indicators that characterize the effectiveness of a person's activity under ordinary conditions and when an emotive situation arises. This instrument, which is called an emocoordinometer, is an electromechanical apparatus that models the sensomotor operator activity involved in following and tracking. This sensomotor activity is fairly typical of a number of operator vocations. As the name implies, the emocoordinometer is an apparatus for studying the capacity for sensomotor coordination and emotional stability. The level of emotional stability is found by recording and comparing indicators of the formed sensomotor activity under normal conditions and under conditions in which an amotion-producing stimulus is applied. The sensomotor activity performed is following a curved target band with a complex configuration through which the test

subject is supposed to move a metal pin (view finder). The test subject controls the movement of the view finder by moving a handle and pedals.

The performance of dynamic tracking on the emocoordinometer is fundamentally different from existing coordinometer methods, in that the view finder is not controlled directly by the hands and feet, but through the medium of electric motors. By pressing on the pedals and moving the handle, the test subject sets into motion the operating gears of the slide bars of the rheostats through which voltage reaches the electric motors. The more the handle is /154
slanted or the more the pedals are turned, the greater the current that reaches the motors, and, consequently, the more rapidly the view finder moves. Turning the pedals and slanting the handle away from a certain middle position reverses the rotation of the motors, which changes the direction of the view finder's movement. When the handle and pedals are in the middle position, the circuit is broken, and this stops the view finder. There is a complication here: this middle (neutral)) position is not fixed. An insignificant movement of the handle or pedals closes the electric circuit and, consequently, sets the view finder in motion. Whereas the pin on the well-known coordinometers of Rupp or Mede stops when a person stops moving the handles, the view finder on the emocoordinometer does not stop when a person stops operating the apparatus. It continues to move, and its speed and direction are determined by how the handle is slanted and the pedals are turned at that point. This results in a marked change in the conditions of the experiment. During the first exercises, one may often hear the test subjects exclaiming: "Where is it going? I'm not doing anything!" etc.

Moving the view finder by means of electric motors corresponds to the actual conditions involved in controlling semiautomated systems, in which the operator's controlling action is not aimed directly at the object being controlled, but only at the appropriate operating gears through which the necessary control result is achieved. Psychologically, this factor is of fundamental importance, since is serves to contrapose purposeful, conscious and active volitional action to the blind forces of a machine that has been set into

motion; these forces unwaveringly continue a given movement until the operator takes a step that is adequate to stop them or to change the character of the movement. When a person does not have abilities and skills sufficient to cope with the machine forces that have been set into motion, the spontaneity of their action generally produces emotions of fear and may lead to tension and confusion. This feeling is rather familiar to everyone who has stood before a machine tool or sat behind the wheel of an automobile or other moving system for the first time.

By means of mechanical gears, the electric motors move the view finder vertically and horizontally in the plane of the metal plate on which the curved target band is mounted. Combining these movements makes it possible to direct the view finder along any trajectory in this plane. Contact between the brush of the view finder. /155
and the target area closes the circuit of the electric counter that records the correct-tracking time. When the view finder goes outside the band, its brush makes contact with a field that is electrically insulated from the target area and it closes the circuit of the error counter. The thrid counter recores the total working time.

At different time intervals, which vary with the complexity of a given section of the target area, small lights (leaders) light up in a sequence at the bends in the target area. According to the instructions, the test subject should follow the "leaders" without lagging behind; he has the right to move ahead of them.

The readings of the counters are processed in the following manner: the correct-tracking time, i.e., the time during which the view finder is in the target area, is divided by the total time spend on performing the entire exercise. The resulting fraction is the tracking coefficient for this exercise. The tracking coefficient is a certain measure of the subject's success in performing the exercise. The ratio of the time during which the view finder is in the target area to the total time spent is used to judge the quality of the work performed. In addition, we also introduced a correction coefficient for the total working time. The following consi-

derations make it mandatory that the total working time be taken into account: first, it is perfectly natural to suppose that, all other conditions being equal, slower work will be more accurate (at least within certain limits, until the test subject has developed his optimum rhythm); and second, while the ratio of the time during which the view finder is in the target area to the total time for performing the work provides a qualitative characterization of the performance of the exercise, the total time spent on performing the exercise provides a quantitative characterization of "productivity." Assessment of work results is correct only when both indicators are taken into account - the quality of the work performed and the time spent on this work.

It may seem at first glance that the total time has already been accounted for in the tracking coefficients. But this is not so. The ratio that we have obtained merely characterizes the qualitative side of the work. One may be convinced of this by means of a simple example: let us say that test subject A performed an exercise in 400 seconds and spent 200 seconds in the target area. Test subject B performed the exercise in 200 seconds and spent 100 seconds in the target area. We find that the tracking coefficient for test subject A is 200/400 = 0.5 and that it is the same for test subject B, 100/200 = 0.5. Both test subjects show identical accuracy in their work, and their tracking coefficients are equal. But test subject A needed twice as much time as test subject B to obtain the same result. /156

This indicates that there is no question that this indicator must be taken into account when recording work on the instrument and all the more when ascertaining individual differences.

In order not to have to use two indicators (for the accuracy of the work and for the time spent) to compare the work of the test subjects, we introduced the time coefficient, to which the correction of the tracking coefficient was applied.

The time coefficient is found by dividing a constant magnitude — 330 — by the total working time. This constant magnitude is

the time during which "the leaders" move from the beginning to the end of the program. If the time taken by the test subject to perform the exercise is equal to 330 divisions of the counter, then he has not lagged behind or moved ahead of the "leaders" and the correction coefficient will be equal to 1. By multiplying the time correction coefficient by the tracking coefficient, we obtain a magnitude that characterizes the work performed in terms of both its quality and the time spent.* We shall use the term "success coefficient" for this magnitude.

Thus, the general formula for calculating a subject's success in working on the emocoordinometer takes the following form:

I. $K_{suc}=K_{tr} \cdot K_{ti}$, where K_{suc} is the success coefficient, K_{tr} is the tracking coefficient and K_{ti} is the time coefficient.

II. $K_{tr}=\frac{t}{T}$ where t is the correct-tracking time and T is the total working time.

III. $K_{ti}=\frac{C}{T}$, where C is a constant (330).

We shall insert $K_{suc}=\frac{t}{T} \cdot \frac{C}{T}=\frac{tC}{T^2}$ in I.

The emocoordinometer was built in order to implement one of the simulation methods developed by Ye.A. Mileryan for psychological selection of pilots. The data of the present study were largely collected by the author during selection of cadets at one of the higher military-aviation academies.

All those who participated in the study were examined by a special medical commission and were pronounced fit for flight service in the Air Force. /157

*All the entries in the record sheets and all the calculations were done using the conventional units of the counter readings, rather than absolute magnitudes of time. On our instrument four divisions of the counter are approximately equal to one second. Hence, it is not difficult to calculate that the time taken by the "leaders" in moving through the program is equal to 330 seconds divided by 4, i.e., 82.5 seconds.

The method used in doing the studies of emotional stability was as follows: the test subject was given detailed instructions concerning the performance of the first series of exercises, and then he performed a trial exercise, whose results were not entered in the record sheet. The first series consisted of six exercises, during which the test subject had to move the view finder through the target area as accurately as possible and without lagging behind the "leaders." This series was aimed at accomplishing two things: first, the test subject was trained to work on the instrument; and second, on the basis of the average success coefficient obtained from the six exercises, it was possible to draw conclusions concerning the applicant's capacity for coordination of movements.

It was assumed that in the course of the six exercises (plus one trial exercise) the test subjects should form sensomotor activity at a level that would preclude the generation of emotion inherent in the first exercises. For this reason, the average success coefficient obtained in the first series became the control for comparison with the average success coefficient of the second series, in which the test subject was subjected to an emotion-producing factor.

Three exercises were performed in the second series. The instructions for this series pointed out that if the test subject made an error, i.e., if the view finder moved outside the target area, he would be subjected to an electric current. In all other respects the exercises of the second series were perfectly similar to the exercises of the first series. Electrodes in the form of a wristband and a ring were attached to the test subject's free hand. Through these electrodes the test subject was subjected to stimulation by an induction current with a strength of up to 150 microamperes, which was turned on automatically whenever the brush of the view finder made contact with the field of the program plate, in whose plane the curved target area was located. The strength of the current was maintained by the experimenter at the same level throughout the experiment with the aid of a microamperemeter and a

potentiometer. The pulsating current passing through the integument from the wrist to a finger was unquestionably safe for the subject. At the same time, it produced rather unpleasant painful sensations, which was indicated by shaking of the hand through which the current passed and by the entire set of external expressions characteristic of the emotions of pain.

Objectively experienced emotion may be recorded in terms of changes in vegetative functions. We undertook a special series of experiments in which a pulse curve was recorded in ink by an oscillograph as the subjects worked on the emocoordinometer. /158

The emotional-stability coefficient was determined by comparing the results of the first and second series of experiments. This coefficient was found by subtracting the average success coefficient of the second series of experiments from the average success coefficient of the second series of experiments. Naturally, we considered the emotionally stable subjects to be those who had higher results in the second series or at least did not do poorer work in comparison with the first series.

Analysis and summarization of the experimental data obtained showed that 77.3% of the test subjects had higher results in the second series of experiments, and only 22.7% had poorer results when subjected to the electric-skin stimulus. This suggested the conclusion that either the absolute majority of our test subjects are extraordinarily emotionally stable, or that the emotion of pain is a factor that has a primarily salutary effect on the progress of activity, or that our chosen method was causing us to deviate from the study of the qualities in which we were interested. Analysis of the data on the record sheets provided us with yet another magnitude that cast doubt on the correctness of the methodological techniques that we had used.

We calculated the magnitudes of the mean deviations of the emotional-stability coefficients for those who did better work with the emotion-producing stimuli and for those who had poorer indicators when subjected to the electric-skin stimulus. The mean deviation

for positive emotional stability was +0.11, and for negative emotional stability it was -0.04. This indicates a predominant trend toward higher results for the majority of the test subjects in the second series of experiments. The curve shows a very insignificant drop in the indicators of a relatively small number of test subjects, while most of the test subjects inproved, and to a considerable extent. At the same time, objective observations of the test subjects' behavior during the experiments convinced us in every case that the test subjects found the emotion-producing pain stimulus to be unpleasant. In the course of these observations, we often saw how the test subjects' actions were disorganized, especially when they were first subjected to the electric-skin stimulus. These observations and common sense clearly conflicted with the data obtained.

True, we subsequently had a chance to be convinced that the /159
electric-skin stimulus, while subjectively perceived as unpleasant, stimulates activity under certain conditions. A more thorough analysis of the record-sheet data obtained made us turn our attention to the fact that the majority of the test subjects who did poorly in the first part of the exercises, i.e., produced very low results in the first series of exercises, showed a positive and rather high emotional-stability coefficient. In order to make sure that this was a regular phenomenon, we selected and compared the success coefficients of the test subjects who had an average success coefficient of less than 0.30 (the arithmetic mean of the average success coefficients in the first series for all the test subjects was 0.44) in the first series (which had no emotion-producing stimulus). There were 21 subjects in this category. Here we present Table 1, in which these test subjects are listed in descending order according to their indicators for the first series.

TABLE 1.*

TEST SUBJECTS' EXPERIMENTAL RESULTS FOR THE TWO SERIES

No.	Average success coefficient in the first series	Average success coefficient in the second series	Emotional-stability coefficient
1	0,29	0,35	+0,06
2	0,29	0,43	+0,14
3	0,29	0,30	+0,01
4	0,28	0,34	+0,06
5	0,27	0,42	+0,15
6	0,26	0,33	+0,07
7	0,26	0,46	+0,20
8	0,26	0,33	+0,07
9	0,26	0,34	+0,08
10	0,24	0,25	+0,01
11	0,23	0,46	+0,23
12	0,23	0,27	+0,04
13	0,23	0,18	−0,05
14	0,23	0,28	+0,05
15	0,22	0,36	+0,14
16	0,22	0,36	+0,14
17	0,22	0,38	+0,16
18	0,22	0,44	+0,22
19	0,20	0,20	0
20	0,20	0,40	+0,20
21	0,18	0 45	+0,27
	0,24	0,35	+0,11

* Translator's note: Commas in numbers represent decimal points.

As may be seen from this table, of all the test subjects who had poor results in the first series of experiments, only 1 (No. 13) had an even lower indicator in the second series and one (No. 19) had identical results in both series. All the rest had better results. The average increment in the second series for this group was +0.11. This is unquestionably not fortuitous. /160

It is perfectly obvious that when the ability is at a low level of formation, the electric-skin stimulus has no apparent effect. We believe that the reason that the indicators of this group of test subjects rose in the second series is that the six exercises of the first series were not enough for them to have formed the activity. As we have said, one of the basic principles of this method is the principle of studying changes in formed activity that appear due to the effect of the emotion-producing factors (Ye.A. Mileryan).

In order to make it possible to judge individual differences on the basis of changes in activity due to the effect of a stimulus that is uniform in strength, it is necessary that this stimulus be applied at identical levels of formed activity. Only when this is so is it possible to compare the test subjects among themselves. This methodological requirement is based on the principle of determinism in psychology, which S.L. Rubinshtein expressed in the statement that "external causes act through internal conditions"[26]. As an external cause, painful stimulation is expressed in activity in different ways under different conditions, which we take to mean the psychic state of the test subject after the first series of experiments.

The affective state produced by an inability to handle the assignment, when admission to the academy depends on performing this assignment, unquestionably had a greater effect than the electric-skin stimuli that we applied.

Numerous cases have been described in the literature in which people in a state of strong emotional excitation failed to react to injuries that sometimes were severe(A.M. Filomafitsky, S.M. Dionesov, H. Beecher [27]). Apparently, this can be explained in terms

of A.A. Ukhtomsky's laws of dominant relationships; he wrote that "...the fate of a reaction in the central nervous system is decided /161
not by the potentials of the sending center, but by the potentials of the reaction-determining center at a given point in time. [28]" The initial functional state of the organism, and above all of the nervous system, is one of the basic criteria of a person's individual reactivity to painful stimulation.

It is perfectly obvious that in the case of this group of test subjects the process of developing the skill of controlling the view finder was going on during the seventh, eighth and ninth exercises, and that this process was still so intense that it was itself a strong emotion-producing factor; against the background of this factor, the electric-skin stimulus did not produce the effect that we had had a right to expect. Thus, the average indicators of these test subjects in the second series did not provide a picture of the emotional changes that should have taken place in response to the painful stimulation. In addition, in this case the first series of experiments could not serve as a control for comparison with the second series, since the activity had not been formed even to a minimum extent in this series, which conflicts with a basic principle of our method.

We established by experimental means that on our instrument it is possible to observe a clear picture of changes in activity due to the effect of emotion-producing factors for the purpose of ascertaining individual differences with respect to emotional stability, when the success coefficients of the first series are between 0.50 and 0.60, i.e., somewhere within the limits of the average indicators. When the indicators for coordination of movements are high (above 0.60), determination of emotional stability on the basis of the difference between the success coefficients of the first and second series also proves to be incommensurable with the indicators of the test subjects of the middle group, who had results between 0.30 and 0.60 in the first series of experiments. This is explained by the generally accepted proposition that the higher the level of a formed skill, the smaller the effect on it of any kind of hindrance, including emotional feelings (Ye.I. Boiko, N.I. Krylov [29]).

TABLE 2.

DATA CONCERNING THE EFFECT ON THE TEST SUBJECTS OF THE OUTSIDE STIMULI

	Number of test subjects	Average success coefficient in the first series for six exercises	Average success coefficient in the second series for three exercises	Average emotional stability coefficient	Number of test subjects with positive emotional stability	Number of test subjects with negative emotional stability
All test subjects	97	0.44	0.51	+0.07	76 persons 78.35%	21 persons 21.65%
					mean +0.11	deviation -0.04
Those who had a success coefficient higher than 0.30 in the first series	76	0.50	0.56	+0.06	56 persons 73.3%	20 persons 26.3%

On the other hand, if the test subject has indicators that are close to the limit, any outside stimulus can affect the productivity of the work being performed. Table 2 presents data obtained for 97 test subjects. /162

Analysis of these data shows partial changes in the distribution of the test subjects with respect to emotional stability. There was an increase in the percentage of test subjects with negative emotional stability and a corresponding decrease in the percentage of test subjects with positive emotional stability.

Nonetheless, the ratio between these magnitudes remained quite improbable. To be specific, 73.3% of the test subjects were shown to be emotionally stable, and only 26.3% were shown to be emotionally unstable. Although a distribution of this kind is probably possible in principle, we had doubts as to whether or not the constantly rising level of the coordination ability being developed had an effect on these results.

In order to eliminate the effect of the growth of the ability being formed on the emotional-stability coefficient that we were seeking, we began to use as a control the average coefficient of the last two exercises of the first series, rather than the average coefficient of the first series of exercises. It is not by chance that we chose as our control the average magnitude for the fifth and sixth exercises of the first series. It was logical to assume that the last two exercises would produce better results and would be more stable than the preceding four. In order to be certain of this, we constructed an ability-formation curve on the basis of the average indicators for each of the six exercises of the first series for 97 test subjects.

The curve obtained does in fact rise sharply up to the fourth exercise, but in the fifth and sixth exercises the rise becomes considerably more gradual. Despite the fact that in the sixth exercise the average success coefficient computed for the entire group was higher than in the fifth, we selected as our control not this average coefficient, but the average success coefficient obtained for the two exercises - the fifth and the sixth. Calculations showed that the average success coefficient for the fifth and sixth exercises was considerably more reliable and higher than the average coefficient for the sixth exercise alone, which is explained by /163

TABLE 3.

DATA CONCERNING CALCULATION OF THE EMOTIONAL-STABILITY COEFFICIENT

	Average success coefficient for the 5th and 6th exercises of the first series	Average success coefficient for the second series	Average emotional-stability coefficient	Number of test subjects with positive emotional stability	Number of test subjects with negative emotional stability
				51 persons mean deviation +0.08	46 persons mean deviation -0.10
For all test subjects (97 persons)	0.52	0.51	-0.01		
For those test subjects who had an average success coefficient higher than 0.30 in the 5th and 6th exercises (83 persons)	0.56	0.54	-0.02	39 persons mean deviation +0.08 47%	44 persons mean deviation -0.10 53%
For those test subjects who had an average success coefficient lower than 0.30 in the 5th and 6th exercises (14 persons)	0.24	0.34	+0.10	12 persons mean deviation +0.12	2 persons mean deviation -0.04

chance fluctuations in the success of individual test subjects.

Table 3 shows the data concerning the emotional-stability coefficient calculations in which the average success coefficient for the fifth and sixth exercises of the first series was used as the control.

Above all, it may be seen from Table 3 that for the entire group of test subjects the average success coefficient for the fifth and sixth exercises rose from 0.44 to 0.52, and there was a similar increase to 0.56 for those test subjects who had a success coefficient higher than 0.30 in the fifth and sixth exercises. There was a sharp change in the percentage of test subjects with positive emotional stability. Whereas previously the majority of test subjects improved when they were subjected to the electric-skin stimulus, now the number of subjects with negative emotional stability exceeded the number of subjects who showed positive emotional stability. /164

Thus, it turned out that there were 39 test subjects with positive emotional stability, which constituted 47% of the subjects, while there were 44 subjects with negative emotional stability, which constituted 53% of the subjects. The mean deviation between the success coefficient for the fifth and sixth exercises and the average success coefficient for the exercises of the second series, in which an electric-skin stimulus was applied, was 0.02. There is no question that these results more adequately reflect the effect of painful emotion on the progress of activity. In contrast, when we used as a control the success coefficient for the six exercises of the first series, we encountered unwarranted averaging of the results, with all the consequences flowing therefrom.

The average success coefficient for the six exercises was very low because the first exercises were especially difficult for the test subjects, who had the low results characteristic of the initial stage of mastering any ability, when the transition is being made from a lack of knowledge and ability to a certain amount of knowledge and ability.

The test subjects' low indicators in the first exercises caused the magnitude of the average tracking coefficient of the first series to be greatly understated. Because of this, the average tracking coefficient of the second series often proved to be lower than the average tracking coefficient of the first series, even though the test subjects were subjected to a painful stimulus during the second series. Improvement of the skill, which continued during the seventh, eighth and ninth exercises, obscured the effect of the electric-skin stimulus. All this indicated the need to improve the method used in processing the data obtained, in order to make it possible to judge the effect of emotions on the activity modelled in the experiment.

3. The Dynamics of Emotional Feeling as a Criterion of Emotional Stability

/165

In the preceding section we made an attempt to analyze the test subjects' behavior during the development of the initial stage of a sensomotor skill. In this connection, we were more interested in analyzing the results of the exercises of the first series. We turned to the second series only in order to use the average success coefficient of the three exercises with the electric-skin stimulus to derive the emotional-stability coefficients. However, the results recorded in the record sheets of the observations of the test subjects' behavior duirng the second series of experiments provided a great deal of material for reflection and for preparing a deeper analysis of the dynamics of the emotional feeling that developed during the test subjects' performance of the exercises of the second series of experiments.

First of all, it is noteworthy that the test subjects' reaction to the electric-skin stimulus in the first exercise is different from their reaction in the subsequent exercises. Whereas in the first exercise with the electric-skin stimulus the absolute majority of the test subjects did not perform the sensomotor activity as well as before, in the two subsequent exercises the success indicators of many test subjects not only achieved the level of the fifth and

TABLE 4.

THE TEST SUBJECTS' ADAPTABILITY TO THE EFFECT OF THE ELECTRIC-SKIN STIMULI

	Test subjects who had results higher than 0.30 for the 5th and 6th exercises.	Test subjects who had results lower than 0.30 for the 5th and 6th exercises of the first series.
Average success coefficient for the 5th and 6th exercises of the first series	0.56	0.24
Average success coefficient for the 1st exercise of the second series	0.47	0.28
Average success coefficient for the 2nd and 3rd exercises of the second series	0.58	0.38
Number of test subjects whose results improved in the 1st exercise of the second series	18 persons	8 persons
Number of test subjects whose results got worse in the 1st exercise of the second series	65 persons	6 persons
Number of test subjects whose results for the 2nd and 3rd exercises of the second series were higher than their results for the 1st exercise of the second series	81 persons mean deviation +0.14	11 persons
Number of test subjects whose results for the 2nd and 3rd exercises of the second series were lower than their results for the 1st exercise of the second series	16 persons mean deviation -0.06	3 persons

sixth exercises of the first series, but for the most part exceeded it (Table 4). The drop in the indicators at the time of the first electric shocks may be explained by the effect of the orientative reflex produced by the electric-skin stimulus. We repeatedly saw that when the electric stimulation was first applied, the test sub-

jects squeezed the handles, showed motor perseverations and sometimes even temporarily stopped functi-ning, which was manifested by their releasing the control levers. But no matter how great the role of the orientative reaction, it still does not explain all the nuances of the effect of the emotion-producing stimulus on the progress of the sensomotor activity.

A peculiarity of this orientative reaction is the fact that the test subject knew beforehand that he would be subjected to electric shocks. He expected it to happen; what is more, he was afraid to one extent or another of the effect of the ESS. Thus, in this case the orientative reaction is not in response to an unexpected stimulus, but in response to a stimulus toward which there is a certain posture, a certain attitude. Apparently, the results achieved by the test subjects in the first exercise with the ESS depended to a certain extent on the relationship between the expected and foreseen sensation (the posture) and the actual sensation caused by the electric shocks. /166

It may be assumed that a positive emotion should have appeared in those cases in which the test subject foresaw a more complicated situation, i.e., expected the pain to be more acute, than it turned out to be in reality. On the other hand, if the pain from the ESS proved to be greater than expected, a negative emotion appeared. In the case of the majority of the test subjects, this "quest for information" ended in the first exercise; therefore, the subsequent exercises with the ESS did not produce emotional tension capable of reducing productivity.

It is a rather well-verified fact that people adapt poorly to painful sensations, especially to those that are produced by an electric current. In the second and third exercises of this series, the painful sensation from the ESS did not abate, which is indicated /167 by a number of objective indicators and by the statements of the test subjects. Nevertheless, it is perfectly obvious that the subjects imporved their results (see Table 4), and it is very proper to apply the term "adaptation" to this process of improvement. Apparently, adaptation of this kind also takes place when distressing expectation

of the unknown gives way to a feeling of resolution, when a struggle, even if it is a difficult one, has at least begun. It unquestionably follows from what has been said above that emotion must be regarded as a process that develops. For the present, we are able to conclude that there are two stages of emotional feeling. The first stage, which was observed during the initial applications of the ESS and which we covered by means of the success coefficients of the first exercise of the second series, we call the stage of emotional reactivity. The second stage, which in the case of some test subjects began as early as the first exercise with the ESS, but which we are able to judge on the basis of the average coefficient of the second and third exercises of the second series, is the stage of emotional adaptation.

There is every reason to believe that emotional stability is a product of the interaction of emotional reactivity and emotional adaptation, which in turn depend on the excitability of the nervous system, on the degree of mobility of the basic nervous processes and above all on the strength of the inhibitory process, which determines the speed and magnitude of emotional adaptation. Finally, what is most important, the process of emotional adaptation should be regarded as a result of the interaction between cortical processes, not so much at first-signal as at second-signal levels, and the subcortical centers of emotions. We emphasize the role of the cortical processes connected with the second signal system, because it is speech that enables a person who is guided by certain motives to control his behavior voluntarily, which in the final analysis is one of the important factors affecting emotional stability.

It is precisely when emotional stability is understood in this way that we can explain instances in which an individual maintains high work capacity and productivity while undergoing significant vegetative and visceral changes, which we have discussed above.

Thus, emotional stability is an integral characteristic that depends on many factors. Consequently, in determining criteria of emotional stability one must take into account the regularities governing the dynamics of the interaction of these factors. Such

criteria may be determined on the basis of the individual differences that are found at the different stages of an emotional feeling. /168

Despite the fact that in the experiments we found certain general regularities in the behavior of the test subjects when they were subjected to a pinful stimulus, we could not help noticing the extremely significant individual differences among the test subjects, with respect to both emotional reactivity and emotional adaptation. These differences were indicated by the following facts: the extreme values of the success coefficients for emotional reactivity were 1.04 and 0.20, and the extreme values of the adaptation coefficient were 1.1 and 0.28. The respective arithmetic means were 0.28 and 0.58. The results achieved by 83 test subjects fell between these magnitudes. Given the general regularities, which were rather clearly evident, such significant individual differences serve as additional confirmation of the importance of taking this factor into account in the case of vocations that require high emotional stability.

In ranking the test subjects according to their indicators of emotional reactivity and emotional adaptation [30], we proceeded on the following basis: first, those who had higher results in the first exercise with the ESS, i.e., those who were less emotionally reactive, should be more emotionally stable; and second, the more strongly that emotional adaptativeness is manifested, the higher a person's emotional stability.

On the basis of these criteria, it was possible to conclude that those who continued to raise their sensomotor-activity indicators in the first exercise with the ESS and then raised these indicators in the second and third exercises of the second series unquestionably have strong emotional stability. On the other hand, those who had poorer results in the first exercise with the ESS than in the fifth and sixth exercises of the first series and failed to improve their results during the so-called adaptation period, o i.e., in the second and third exercises of the seocnd series, have weak emotional stability.

But there were relatively few subjects in either of these categories. As we have already said, the indicators of the majority of the test subjects dropped during the first applications of the ESS and then rose in the subsequent exercises. It turned out that this group was not homogeneous. This was because some test subjects, though their results dropped in the first exercise with the ESS, raised them so much during the adaptive period that they surpassed the level that they had achieved in the fifth and sixth exercises of the first series. But other test subjects, even though they improved their results in the second and third exercises with the ESS, still did not achieve the control level of the fifth and sixth exercises of the first series. /169

This made it mandatory for us to introduce another criterion, which we called the productivity criterion. On the basis of this indicator, we separated the test subjects with positive adaptation into two subgroups - those with relatively strong emotional stability and those with relatively weak emotional stability. Statistical treatment of the data on the basis of these three criteria made it possible to classify the test subjects according to the quantitative signs of emotional stability, as follows: the quantitative characterization of emotional reactivity (Er) was defined as the difference between the average success coefficient of the control exercises and the average success coefficient of the first exercise with the ESS. As the quantitative characterization of emotional adaptation (Ea), we used the difference between the average coefficient of the first exercise with the ESS and the average coefficient of the second and third exersises of that series. We introduced the emotional-stability coefficient A, which is computed according to the formula $A = Er + Ea$, and the relative emotional-stability coefficient B, which is equal to the ratio of emotional reactivity to emotional adaptation: $B = Er : Ea$.

It is natural to assume that $A>0$ means strong emotional stability, $A<0$ means weak emotional stability, $B>0$ means monotonic stability and $B<0$ means relative stability. The test subjects may be distributed among the four groups in accordance with the values of the coefficients A and B in the following manner:

TABLE 5.

DISTRIBUTION OF THE TEST SUBJECTS ACCORDING TO CRITERIA OF PRODUCTIVITY

Characterization of emotional stability	Criteria		
	Emotional reactivity	Emotional adaptation	Changes in productivity when shifting from optimum to extreme working conditions
1. Strong	low	positive	increase
2. Relatively strong	high low	positive negative	increase
3. Weak	high	negative	decrease
4. Relatively weak	low high	negative positive	decrease

A>0, B>0 — strong emotional stability;
A<0, B>0 — weak emotional stability;
A>0, B<0 — relatively strong emotional stability;
A<0, B<0 — relatively weak emotional stabiltiy.

The distribution of the test subjects in accordance with these criteria is presented in Table 5.

As may be seen from this table, we placed in the category of people with strong emotional stability those whose activity was characterized by increased productivity when they were subjected to the emotion-producing stimulus and who showed low emotional reactivity and positive adaptation. /170

Weak emotional stability was characterized by high emotional reactivity and negative adaptation. Naturally, the productivity of these test subjects always dropped when they were subjected to the emotion-producing actors. The results achieved by the test subjects with relatively strong emotional stability dropped at the stage of emotional reactivity or at the stage of emotional adaptation, but overall their results were higher with the ESS than without it.

The test subjects with relatively weak emotional stability were those whose results dropped due to the effect of the ESS, although they showed either positive adaptation or weak emotional reactivity.

The criteria indicated stem from the essence of emotional stability, which is regarded as a characteristic of the emotional-volitional sphere of the personality. In contrast to the indicators of changes in physiological reactions that indicate the level of emotional reeling, indicators that are used by some researchers, these criteria indicate the presence of those positive qualities that make a person capable to one extent or another of resisting the emotional facotrs acting on him and of maintaining the necessary level of work capacity under extreme working conditions.

The system of criteria that we have proposed may be used to develop psychological selection methods for those operator vocations in which emotional stability is a vitally important quality for the workers to have. /171

CONCLUSION

In this study an attempt was made to provide a psychological interpretation of the concept of emotional stability in connection with other psychic qualities of the operator's personality.

Proceding from the dialectically contradictory essence of emotions, which on the one hand serve as a necessary component of vital activity and on the other hand are a hindrance to the personality's rational experience, emotional stability may be understood as a person's capacity to control his emotional state for the purpose of maintaining the necessary level of work capacity under extreme working conditions. On this basis, it is expedient to regard emotional stability as a characteristic of the personality, rather than as a state. Naturally, though, like any other characteristic of the personality, emotional stability-instability may sometimes take the form of a state.

The level of emotional stability depends on many factors involved in both the biological and social essence of man. Emotional stability is determined, on the one hand, by the features of the individual's nervous system and by the level of the organism's physical state, and on the other hand, by the features of the personality's consciousness and by its intellect, motivational-volitional sphere and sphere of higher feelings.

Thus, emotional stability is a synthetic quality and cannot be determined merely by ascertaining the level of the personality's emotionality.

It is from this standpoint that the question of the methods of studying emotional stability, which cannot be reduced merely to recording the current level of emotional feeling, is resolved. The personality's capacity to resist, restrain and compensate for an unfavorable emotional state may be judged by analyzing the success indicators of its activity.

In the course of the experiments modelling operators' sensomotor activity, we succeeded in making more precise the method of determining the level of emotional stability by comparing the productivity indicators under ordinary conditions with the indicators characterizing activity performed under conditions involving an emotional load.

Statistical treatment of the experimental data made it possible to establish criteria of emotional stability resulting from the interaction of the different levels of the regulation of human behavior. /172

Reactivity and adaptability, which were adopted as criteria of emotional stability, characterize, respectively, the level of emotional excitability and the personality's compensatory potentialities. Productivity as a criterion of emotional stability relates these qualities, making it possible to provide a quantitative characterization of their interaction on the basis of the results of work activity under optimum and extreme working conditions.

Using these criteria, it is possible to establish the individual's level of emotional stability and to classify the test subjects with respect to this quality.

The features of emotional stability that have been found, which are manifested in terms of reactivity and adaptability depending on individual differences, amy be used to take a more differentiated approach in selecting and training operators that is based on the speicfic demands made by a specific vocation on a person's qualities.

REFERENCES

1. Lomov, B.F. Chelovek i tekhnika (Man and Technology). Sovetskoye Radio Press, Moscow, 1966; Mileryan, Ye.A. and O.P. Shvetsov. The General Structure of Operator Activity and Certain Conditions of Its Formation. Voprosy psikhologii, 1966, No. 4; Zinchenko, V.P., N.I. Maizel', A.I. Nazarov and A.A. Tsvetkov. Analysis of Operator Activity. Inzhenernaya psikhologiya (Engineering Psychology) MSU Press, 1964

2. Gurevich, K.M. and V.F. Matveyev. On the Vocational Fitness of Operators and Ways of Determining It. In: Voprosy professional'noy prigodnosti operativnovo personala energosistem (Problems of the Vocational Fitness of the Operative Personnel of Power Systems). B.M. Teplov and K.M. Gurevich, ed. Prosveshcheniye Press, Moscow, 1966.

3. Gor'ky, A.M. Sochinenia (Works). Vol. 28, p. 101.

4. Ibid

5. Kovalev, A.G. On Feelings and Emotions. Voprosy psikhologii, No. 4, 1957.

6. Simonov, P1V. Emotional Excitation and Psychic Mutagenesis. II simpozium po problemam "chelovek-mashina" (Second Symposium on "Man-Machine" Problems) Tezisy dokladov (Theses of the Reports). Moscow, 1966.

7. Spinoza, B. Ethics, Izbrannyye proizvedenia (Selected Works). GIPL, Vol. 1, 1957, p. 456.

8. Pavlov, I.P. Dvadtsatiletny opyt izuchenia vysshy nervnoi deyatel'nosti zhivotnykh (Twenty Years of Experience in Studying the Higher Nervous Activity of Animals). Medgiz, 1961, p. 363.

9. Keller, W. Intelligenzprufungen an Menshenaffen. (Intelligence Tests with Human Apes).

10. Uznadze, D.M. Obshchaya psikhologiya (General Psychology). Tbilisi, 1940, pp. 96-97 (In Georgian).

11. Chernikova, O.A. Study of Emotional Stability Under Conditions of Tense Activity. Tezisy vystupleny na XVIII Mezhdunarodnom psikhologicheskom kongresse (Theses of the Speeches at the 18th International Psychological Congress). Moscow, Vol.2, p. 507.

12. Norakidze, V.G. Tipy kharaktera i fiksirovannaya ustanovka (Character Types and Fixed Posture). Metsniyereba Press, Tbilisi, 1966.

13. Levitov, N.D. O psikhicheskikh sostoyaniyakh cheloveka (On Human Psychic States). Prosveshcheniye Press, Moscow, 1964.

14. Puni, A.P. A Player's Pregame States. Teoriya i praktika fizicheskoy kul'tury, No. 7, 1949.

15. Varshava, B.Ye. and L.S. Vygotsky. Psikhologichesky slovar' (Psychological Dictionary). Uchpedgiz, Moscow, 1931.

16. Platonov, K.K. and L.M. Shvarts, Ocherki psikhologii dlya letchikov. (Essays in Psychology for Pilots) Voyenizdat, Moscow, 1948, p. 131.

17. Platonov, K.K. and L.M. Shvarts. Ocherki psikhologii dlya letchikov. (Essays in Psychology for Pilots), p. 130.

18. Ibid., p. 131.

19. Platonov, K.K. Psikhologiya letnovo truda (The Psychology of Work inaan Airplane). Voyenizdat, Moscow, 1960; Platonov, K.K. Voprosy psikhologii truda (Problems of Labor Psychology). Medgiz, Moscow, 1962; Platonov, K.K. Aviatsionnaya psikhologiya (Aviation Psychology). Moscow, 1963.

20. Yershova, A.P. Emotional Reactivity as a Component of the Capacity for Being an Actor. Voprosy psikhologii, 1968, p. 2.

21. Marishchuk, V.L., K.K. Platonov and Ye.A. Pletnetsky. Napryazhennost' v polete (Tension in Flight). Voyenizdat, Moscow, 1969; Marishchuk, V.L. K voprosu ob emotsial'noi ustoichivosti kursantov-letchikov i vozmozhnosti ee sovershenstvovania s primeneniyem sredstv fizicheskoi podgotovkoi (On the Question of the Emotional Stability of Cadet-Pilots and the Possibilities for Improving It by Using Physical Training Methods). Candidates Dissertation, Leningrad, 1964; Marishchuk, V.L. Psikhologicheskiy otbor letchikov (Psychological Selection of Pilots). Ye.A. Mileryan, ed. Kiev, 1966.

22. Marishchuk, V.L. Izucheniye emotsial'noi ustoichivosti kursantov aviatsionnykh uchilishch (Study of the Emotional Stability of Aviation Academy Cadets).

23. Psikhologichesky otbor letchikov (Psychological Selection of Pilots). Ye.A. Mileryan, ed.

24. Psikhologichesky otbor letchikov (Psychological Selection of Pilots). Ye.A. Mileryan, ed. p. 146.

25. There is a detailed description of the methodological principles and technical features of the instrument's design in the book Psikhologicheskiy otbor letchikov (Psychological Selection of Pilots). Ye.A. Mileryan, ed.

26. Psikhologicheskiy otbor letchikov (Psychological Selection of Pilots). Ye.A. Mileryan, ed.

27. Filomafitskiy, A.M. A Physiological View of the Use of Ethers, Chloroform and Benzine as Substances that Dull Nervous Activity. Voyennomeditsinsky zhurnal, 1949, 1953, Smes' Section; Dionesov, S.M. Bol' i ee vliyaniye na organizm cheloveka i zhivotnovo (Pain and Its Effect on the Human and Animal Organisms) Medgiz, Moscow, 1963; Beecher, H. Relationship of Significance of Wound to Pain Experienced. J.A.M.A., 1956, pp. 161, 17, 1609.

28. Ukhtomsky, A.A. On the Drain of Excitations. Sobrannyye sochinenia (Collected Works). Leningrad, Vol. 1, 1950, p. 222.

29. Boyko, Ye.I. Toward Formulating the Problem of Abilities and Skills. Sovetskaya pedagogika, 1955, p. 1; Krylov, N.I. Dependence of the Process of Automation on the Structure of Action Control. In: Voprosy izucheniya vysshey neyrodinamiki v svyazi s problemami psikhologii (Questions of the Study of Higher Neurodynamics in Connection with Problems of Psychology) Ye.I. Boiko, ed. APN, Moscow, 1957.

30. Zil'berman, P.B. On Assessing the Level of a Person's Emotional Stability During Vocational Counseling and Vocational Selection. In: Professional'naya oriyentatsiya i konsul'tatsiya molodezhi (Vocational Orientation and Counseling for Young People). Kostyuk, G.S., I.M. Nazimov and D.F. Nikolenko, ed. Radyans'ka Shkola Press, Kiev, 1966.

N75 17952

INCREASING THE RELIABILITY OF LABOR OF RAILROAD ENGINEERS

V. S. Genes, Yu. M. Madiyevskiy*

The problem of reliable work of railroad engineers is extremely complex and in recent years has undergone significant changes in a number of its aspects. Being a partial case of a more extensive problem --the labor reliability of operators in the "man-machine" system, it is additionally characterized by a number of significant peculiarities. /173

The problem of the reliability of labor of railroad engineers can be viewed both in the aspect of ensuring safety of motion and in the aspect of obtaining a maximum economic effect.

Maximum economic effect can be obtained only with strict accomplishment of the scientifically designed traffic schedule.

In its turn, the traffic schedule should take into account not only the number, rate, and quality of delivering passengers and freight, but also the material resources expended on transport, such that the achievement of maximum economic effect for each individual engineer will be equal to the schedule's sustainment. Today, the engineers of diesel electric trains also frequently face the problem of conserving electricity, which occasionally runs counter to sustaining the schedule. As a result, some trains are removed from the schedule, the engineers are forced to overexpend energy, and on the whole losses appear instead of savings.

---

*The Academy of Medical Sciences of the USSR Group of Professor V.K. Navrotskiy and the G.S. Skovoroda Laboratory of Engineering Psychology of the Khar'kov State Educational Institute.

One of the most important aspects of the problem is studying the distribution of operator work in time and coordinating the capacity of the operator for its accomplishment. Theoretical analysis makes it possible to isolate two of the most important states, from a practical viewpoint; 1) the state of operator overload, 2) the state /174 of underload.

The condition of overload can be due to a number of factors. Some of them are related to the amount of information subject to processing. Thus, for example, the control panel and the environmental situation (feedback signals) can present so much information to the operator simultaneously that it is not within his power to process the information at the necessary time, or processing is accompanied by great difficulties.

Another complexity related to processing information consists in a deficiency of information for making a well-founded decision. In the process of work of a railroad engineer, practically speaking, the conditions of information overload systematically appear when starting the train from the station and to a somewhat lesser degree, when pulling into a station for a stop.

As a rule, conditions of information deficiency are created during travel at night at a speed in excess of the braking path, in comparison with the length of the visible region of the route, particularly when approaching unseen, unprotected crossings over the railroad right of way.

It should be particularly noted that the so-called primary right of way of railroad crossings, removing legal responsibility for collisions with vehicles stuck on the crossing, does not relieve the engineer of moral traumas or the physical injuries related to these types of occurences. A second example of operations linked with an overload of engineers is making decisions concerning the regime of train movement under specific conditions.

The necessity of taking into account the requirements of the schedule, the profile of the route, the weight of the train, the coupling of the wheels with the rails, signals of the signal lights and choosing a system of connecting the pulling engines for saving electricity or fuel requires a great deal of intellectual effort.

Still another example of the engineers' solving a difficult information problem is choosing the regime of braking for stopping the train at the station.

The second type of overload is due to the necessity of accomplishing a number of controlling motor acts in parallel. For example, when starting the train out from a stop it frequently becomes necessary simultaneously to control the operation of the engine, brakes, sand box, and the signal.

The consequences of overloading the operator, specifically the /175
engineer, can be subdivided according to the time of their appearance into two categories: a) those that occur immediately in the course of overload or immediately following it; and b) remote consequences that develop after many repetitions of overloads.

The first category of the results of overloads is reflected in improper actions of the engineer that lead to accidents, or, in the best case, to non-optimum control.

In a personal regard, it can be accompanied by pronounced emotional reactions with disruption of the higher nervous activity and vegetative regulation of the activity of the internal organs.

The second category of the results of overloads facilitates accelerated aging of the engineer, occasionally leads to the develop- /176
ment of a number of pathological conditions (for example, hypertension, neuroses, ulcer disease, etc.), and in general - to a decrease in the effectiveness of the engineer's labor activity.

Hence, the problem of increasing the reliability of work of railroad engineers is linked with measures directed toward liquidating or at least decreasing overloads.

From the examples of factors that cause engineer overload cited above, the necessity of developing a number of measures by whose aid they can be decreased appears. One portion of these measures pertains to improving special devices for controlling the locomotive, while the other is linked with providing necessary signals on the route for a given run.

The former should include developing automatic devices for selecting speed and automatic brakes to brake from a given initial speed to an assigned speed on a certain portion of the route. During this process, the engineer keeps his obligation to activate the necessary automatic devices for accomplishing the route problems, and of controlling their activity.

The latter should include developing signals for the condition of crossing tie up and tie up of other dangerous regions unseen by the engineer during the day and night.

Increasing the capacity of the search light industry is an unquestionable requirement directed toward improving the psychological working conditions of engineers.

Problems of completely automating the control of trains that have been posed at a number of symposia (for example, at the Leningrad Symposium in January, 1968), have been unattainable on most railroads of the USSR in recent years because of the use of railroad rights-of way as roads for moving pedestrian traffic and cattle in periods of bad road conditions, and because of the saturation of railroads with unguarded crossings.

Ensuring the reliability of engineer work in the condition of underload. The second condition related to the problem of reliability of engineer work and briefly mentioned above is the condition of underloading him with useful information and work.

A similar situation can be observed in a number of operator occupations, where an adequately high degree of automation of the entire production process or individual component processes has been attained. For example, it can exist among operators of petroleum drilling towers, chemical and atomic reactors, and electrical generating stations. It is observed, no matter how paradoxically, among engineers of modern locomotives, pilots of long-range aircraft (upon activation of automatic pilots), and among drivers during work on intercity level-road runs.

Underloading the engineer with useful information requiring certain actions can lead to conversion of conditions of operational calm to the hypnotic state.

It is vital to note that among locomotive engineers this is also made possible by a number of other factors. For example, the increase in speed characteristics of modern locomotives leads to an increase in load of the optic analyzer of the engineer with "noisy" information (flashing by of cross-ties, trees, structures, etc.), and to fatigue and inhibition, which are extended to other regions of the cortex. Evenly paced rocking increases this effect. As a result, the engineer frequently falls asleep, which always leads to a loss of effectiveness of control and occasionally to accidents as well. A characteristic phase of the development of the hypnotic state is breaking the links between the intellectual perception of signals and their logical conceptualization between making decisions and actions. Thus, cases have been observed when a good engineer, moving along at high speed, saw the yellow signal, but in "pressing the alarm button", did not diminish speed at the siren, and rode through the red signal, after which he collided with the "tail" of a train moving along ahead.

Delay of action (decreasing drive, activating the brakes) in response to danger signals during development of the hypnotic state is an extremely frequent phenomenon. Therefore, the struggle with the hypnotic state is one of the most important conditions of increasing the reliability of labor of the engineer and of other operators.

Combating the hypnotic state of engineers includes three elements /177 1) detecting the hypnotic state and determining its degree of expression; 2) measures for changing the hypnotic state into a state of operator calm; 3) measure for preventing an accident when it is impossible to return to the state of operator calm.

The problem of automatically detecting the hypnotic state of the engineer and of measuring the degree of its pronouncement under conditions of a multihour observation of the operator can be solved most easily on the basis of measuring the latent time of certain reactions of the engineers. It is widely known that this index is a highly sensitive indicator of the state of ongoing human higher nervous activity.

During the development of general fatigue, in the initial phase the latent period can shorten with an increase in cortical working capacity. However, this phase poses no danger. The second phase is linked with an extension of the latent period. It is subject to identification and control, since delayed reaction of the engineer is dangerous.

It seems practically convenient to us to subdivide reactions into three groups with respect to the latent period. The first group consists of normal reactions. They are established as the result of experiments conducted on alert engineers.

The second group consists of delayed reactions. Their latent period is greater than the upper boundary of the first group and indicates the departure of the engineer from the regime of maximum alertness. The upper boundary of this group is established depending on the time during which the engineer can relatively safely be distracted from controlling the tracks. However, this time should not exceed two seconds, since a delay in reaction over a greater period of time in observing the signals in response to which the reaction appears can already indicate a significant degree of the hypnotic state.

The third group is a dangerous delay in reactions. The latent period exceeds the upper boundary of the second group, and its maximum duration is established proceding from the maximum permissible speed along the line. Exceeding the upper limit of reactions of the third group already indicates an emergency situation.

Investigations conducted by us on operators of different ages and qualifications on an independently running locomotive (the ChS-2 diesel electric locomotive and on locomotives leading trains), showed that such a division of latent periods into groups is practically justified. Specifically, the group boundaries that make it /178 possible to ensure complete safety of movement at the speed permissible for the ChS-2 diesel electric locomotive were successfully chosen.

The most important element of the system of revealing the hypnotic state by the aid of measuring the latent reaction period is choosing the controlled reaction itself.

Today, the principle of controling the alertness of engineers according to their reaction to a sonic signal is widely deseminated. However, experience shows that reactions to a sonic signal are easily carried out even in a state of relatively deep sleep (for example, turning off the alarm clock without waking up), not to mention the less deep hypnotic states (somnolence, sleeping with the eyes open,

etc.) Hence, the reflex to the sonic signal not only does not ensure unconditional identification of the early hypnotic states, but frequently does not even insure identification of quite deep sleep. This particularly pertains to cases when long-term training leads to the development of the "guard reaction" to the sonic signal.

Therefore, another theoretical principle should be used as a basis for selecting the controlled reaction. It seem vital to us to control the condition of the analyzer that is subject to the greatest functional load and on whose state the optimum execution of operator functions primarily depends. Inasmuch as the visual function is most important for engineers, and the greatest load in fact falls on it, it is vital to choose the reaction whose receptor element is the visual analyzer in the capacity of the control reaction. The photo-stimulus is a convenient signal for this reaction. The question of the place of appearance of the signal used to test the reaction is very important. It should mandatorially be in the working field of vision of the engineer, and at the same time should not hinder observation of the operating objects. This problem is solved separately for each type of locomotive.

The intensity of the light signal should vary depending on the conditions of illumination. It is best if this can be carried out automatically to maintain adequate contrast with the background. In the simplest case, regulation can be carried out by the engineer himself, within limits of certain assigned values, so that the stimulus does not exceed the limits of moderate force.

Today, most engineer alertness control systems use the so-called alertness button which the engineer must press to confirm his alertness as an effector element. These alertness buttons and pedals (for example, in the English system) are not directly linked with the working operations of the engineer. /179

Hence, the control reaction creates additional loads for the engineer. In those cases when natural interruptions between working operations comprise several minutes or more, the control reactions should be artificially forced. However, by their character they should maximally approximate natural operations. For engineers, the working operation that the control reaction should approximate is the reaction of braking the train at the appearance of the danger signal. It is linked with compressing the grip of the braking valve. Therefore, it seems efficient to introduce pressing the alertness button upon compressing the grip of the braking valve as the effector element of the control reaction. On the whole, during this process, the controlled reaction to the hypnotic state is seemingly a duplicate of the elementary reaction to danger. This reaction does not enter into specific relationships with the basic working operation ensuring safety of movement, and, on the other hand, aids in its conditioning.

It was already noted above that the introduction of controlled reactions is necessary in those cases when the interval of time between working operation comprises several minutes or more. This is related to the fact that the time of possible transition from the wakeful state to the hypnotic state also comprises several minutes. However, during the initial stages of the hypnotic state the time of falling asleep can significantly shorten. Therefore, the intervals between repeated tests of the control reaction during the initial stage of hypnoses should also be shortened. Thence, it follows that the program of supplying the controlled signals should have an inverse relationship with the value of the latent period that characterizes the state of wakefulness or the stage of the hypnotic state.

Practically, depending on the three groups of latent periods described above, three groups of periods of supplying the control signals can also be established. Thus, the group of normal latent periods corresponds to the group of longest intervals between control signals (the first program, from 60 to 120 sec.). The group with

delayed reactions, which can indicate the development of the initial phase of the hypnotic state, corresponds to a group of shortened periods between controlled signals (the second program, approximately from 30 to 60 sec). The group with a dangerous delay in reactions /180 corresponds to the most frequent supply of control signals (the third program, from 15 to 30 sec).

Within each group, the signals should occur with nonuniform time intervals, so that the time reflex cannot develop.

Unfortunately this is not taken into account in the alertness control systems presently operating and installed in the ChS-2 diesel electric locomotives in Czechoslavakia, as well as in the Soviet installation for prescribed uncoded track regions.

Upon withdrawing the engineer from the hypnotic state to the wakeful state, the feedback system of the signal sequence program of the control reaction returns it to the first program. For this purpose, no less than a 5-fold confirmation of the wakeful state, indicated by the appropriate latent periods of control reactions is required, which negates the random character of transition to the wakeful state with a probability of nearly 95%.

The system of controlling the wakeful state of the engineer, identifying hypnotic states and the degree of their expression should be supplemented by a system of recording the dynamics of the state of the engineer. This can practically be carried out by means of recording transitions of the program of supplying signals of the control reactions on the tape of the velocity meter. As a result, the possibility of post-trip determination of the state of the engineer at any time during the trip and in any region of the route is created.

On the basis of analyzing these recordings, one can objectively answer questions of the occupational suitability of engineers,

questions of establishing the work regime, shift arrangement, assignment of leaves, etc.

The described system of control during checks on short and long runs, or during the day and night has demonstrated high sensitivity to changes in the state of engineers.

The system of determining transitions to the state of wakefulness of engineers creates a basis for its timely stimulation.

It was already indicated above that the basic factor permitting the development of hypnotic states is an inadequate amount of incoming useful information, predetermining a decrease in the level of operator activity. Therefore, for stimulating wakefulness of the engineer during the initial stages of the development of the hypnotic condition, great significance attaches to increasing the rate of procession of signals of the control reaction. During the deeper stages of the hypnotic state, other analyzor systems can be used in the capacity of additional stimuli. Specifically, with the basic light stimulus, the additional stimuli can be sonic and thermal tactile stimuli linked to the light stimulus with a certain lag-time. It is rational/181 to use a stream of cold, pure, air as the thermal tactile stimulus.

A very significant stimulating factor is the psychophysiological factor of creating the presence of constant control over the condition of wakefulness. Psychophysiological analysis of the effect of this factor shows that at first it causes a negative reaction in a number of engineers (as do all measures for controlling alertness); they view these measures as a lack of trust in their activity and as factors that require a constant concentration of attention on controlling activity.

However, working on this device over the course of 1-2 hours, in most engineers, is accompanied by the extinction of the negative attitude, although two contrary approaches to the control system are

maintained in their consciousness: on the one hand, they understand that this system guarantees their security against the great misfortunes related to possible loss of alertness, and against accidents with a threat to their own lives, while on the other hand, it deprives them of a certain amount of freedom characteristic of the work of engineers of modern locomotives, as distinct, for example, from that of automobile drivers.

Only in a case in which the engineer is immediately acquainted with the operation of the control installation as an inseparable part of the control system in the process of training him to drive the locomotive does he perceive it with complete positiveness.

For supporting the state of wakefulness of the engineer and the reliability of his work, the hygenic situation of the working area and the general order regulating his activity have determinable significance. Thus, great significance attaches to the cab heating system. On the ChS-2 diesel electric locomotive, for example, a warm stream of air from the heater blows in the engineer's face, dries the mucous membranes, creates tears in his eyes and accelerates fatique and the development of the hypnotic state. At the same time, a stream of cold air strikes the engineer's back, causing unpleasant sensations and detracting the engineer's attention from observing the tracks.

According to the existing regulations of the work of the engineer, in order to maintain his alertness, it is mandatory to greet duty officers when passing all stations, opening the window of the cabin. As a result, air pressure sharply changes in the cab during high speed and pain develops in the ears (as is the case with a sharp change in altitude during aircraft flight). For 10-20 seconds, the /182
engineer loses the state of operator calm. This is also caused by a sharp wind or a cold wind in winter, causing the development of tears. At night engineers are obliged to turn on the cab light when

going through stations, and as a result they lose their adaptation to the track illumination for a short time. All this severly diminishes the reliability of engineer work.

A significant value also attaches to the order of engineer work. Presently, the engineer himself drives the locomotives for the entire shift; his assistant carries out only auxillary functions, although as a rule he is entitled to drive. A psychophysiological investigation shows that the alternation of two drivers every 2-2.5 hours significantly diminishes fatigue and the possibility of the hypnotic state. This is related to the variable character of activity of the engineer to alternation of tension of different nerve centers, to an increase in physical mobility, and, which may be most important psychologically, to a decrease in the sense of responsibility during the time in which the engineer's assistant goes to work, then a new increase upon his return to the engineer's chair. During continuous work in the capacity of engineer over the course of several hours, the sense of responsibility and of danger of careless actions gradually decreases. During this process, a restructuring in the general working schedule of engineers appears. As the result of less fatigue during the alternation of two engineers, there can be an increase in the "arm" of the graph line of the locomotive brigade, calculating that over a single departure from home (trip) the brigade works three or four shifts rather than two (with consideration of rests between half trips "there" and "back" to the brigade building). As a result, there will be a 1.5 - 2 fold increase in the interval of time between shift, which permits the engineer fully to restore his strength before the next trip. Presently, engineers have to spend nearly all of their time at the engineer dormitory sleeping, which has a negative effect on their mood (little contact with families, no time for cultural distractions, etc.), and consequently, on their working capacity as well.

The order of work of engineers and hygienic conditions that presently exist to a certain extent create an unfavorable psycho-physiological background for combating the development of hypnotic states.

Therefore, in the system of ensuring the reliability of labor of the engineer, a system to prevent accidents in case the engineer falls asleep is provided for. This system, including an "autostop", activates in case the latent period of the control reaction extends beyond the limits of duration of the third group of the latent period /183 i.e., the reaction is absent not only in response to the flight signal but also in response to the sonic signal and the stream of air.

It was indicated above that during the relatively shallow hypnotic state and occasionally even in sleep, the capacity to react to a sonic signal in the absence of a reaction to the light signal can be maintained. In other words, the engineer can occationally travel with open eyes but respond to the sonic delay signal with pressure. In order to exclude this possibility, the system should provide for a circuit preventing movement with a responsive reaction only to the sonic signal. For example a response reaction three times in a row only to the bell should activate the "autostop".

Combining control subsystems of the state of alertness of the engineer into a single system, stimulating alertness during the initial forms of development of the hypnotic state, and the "auto-stop" upon the engineer's falling asleep make it possible to guarantee accident-free work of the engineer in regimes of diminished loading of his useful activity.

Since the work of the engineer consists of alternation of periods of increased and diminished load, as was already mentioned, the system of controlling the state of the engineer should be activated only in periods of diminished load in order not to create an additional

load in periods of engineer overload. With this goal, sensors of change in the position of operating instruments of control are mounted on the instruments, by whose aid the circuit blocking the system of controlling the engineer's state is activated.

As a result, the control system activates only if the engineer has not carried out basic working operations over the course of an assigned period of time (about 90 seconds) (gaining speed or braking). Naturally, the control system also does not operate at stops.

Hence, in activating in periods of physical nonactivity of the engineer, the controlling system supplements the inadequate flow of useful information, interrupts the monotonous stream of information noise, and prevents the development of hypnotic states. Additionally, as with any activity, it is also a certain additional load for the engineer. Of interest is an attempt to estimate the value of this load. The physical (pressing the button) is very small. The psychophysiological load cannot presently be directly measured. However, a certain approximated comparison with the ordinary load of the engineer can apparently be carried out. For this purpose, we suggest examining the control reaction as an elementary condition-reflexive act, and to isolate its analogues in other forms of activity. For example, the psychophysiological reaction to the appearance of the /184
yellow signal, as a minimum consists of the following acts: 1) determining after which signal this color appears, red, green, or yellow in the preceding signal; 2) which signal it is, the overrun or entry to station signal; 3) comparing the speed of the train with that permitted for the yellow signal; 4) determining the distance to the next signal; 5) determining which train is moving ahead (a freight train or passenger train); 6) whether or not the train moving ahead can be received on a side track to free the main track for passage of the given train; 7) is it necessary to brake, gain speed, or do nothing; 8) determine the profile of the track (incline, rise, or curve);

9) the condition of the track (wet rails, ice covered, dry rails, leaf covered rails); 10) determine the weight of the train; 11) the type of freight (for determining the permissible positive or negative acceleration); 12) which operating control instruments should be activated; 13) the order of employing them; 14) estimating the result of employing them; 15) correction of action. Each of these acts is more complex than the act of the control reaction, therefore one can only compare the complex reaction to the yellow light with the control action according to the minimum of excess in complexity. At the same time, the complex reaction can still prove to be several times more complex in comparison with the control. However, even according to the minimum coefficient of complexity, all working operations of the engineer exceed the control reaction by more than 10-fold. If one considers that over a working shift of 360 minutes the locomotive engineer accomplishes a minimum of 360 operations, of which about half are accompanied by physical action, then over the remaining time of 180 minutes in the alert state the engineer can accomplish no more than 120 control reactions. Thence, it follows that additional load from the control reaction at a complexity coefficient of 0.2 cannot comprise more than 1/300th of the operating load (0.3%), and in reality is a great deal less. During this process, it should be taken into account that the emotional coloring of the working reactions, frequently accompanied by a pronounced vegetative component, does not practically extinguish, while at the same time the control reactions lose their emotional coloring over a short period of time during the latent periods of the first group, maintaining it only under the effect of the other groups. /185

Test runs have shown that in most engineers the latent periods of the control reaction become stable and develop into the first group after 10-15 repetitions. During travel in the premorning hours, after several night hours of work, the frequency of entry into the second group of latent period increases. In only one case (a 56 year old engineer with hypertension) were about 60 repetitions required to obtain stable latent periods of the first group.

N75 17953

"OPERATIONAL CALM" AND THE OPTIMUM REGULATION OF HUMAN WORKING CAPACITY

Ye. P. Il'in*

Increasing working capacity, primarily by optimum regulation of human working capacity is a complex psychophysiological problem. Without touching on the entire problem, in this chapter we shall dwell only on one of its comparatively little-studied questions: the significance of the initial background (calm) for obtaining high working capacity.

An important quality of the organism in the struggle for existence has been its capacity to maintain a constant environment within itself by maintaining a number of physical, chemical, and physiological constants of the body. Such a capacity ensures the organism independence of its vital processes from changes occuring in the environment (Claude Bernard).

The American Physiologist V. Kennan expanded the concepts of C. Bernard and suggested that relative dynamic constancy of both the internal environment of the organism and certain of tis physiological functions (circulation, respiration, temperature regulation, basal metabolism, and the activity of the individual endocrine organs) be called homeostasis, i.e., the capacity to maintain its constancy.

Presently, a concept has appeared concerning the expediency of the term homeostasis, which means the structure and character of neural reactions and constant appearance of the basic properties of nervous activity characteristic of the normal man. Obviously, the questions taken up by us pertain to this type of homeostasis. A number of data indicate that the functions of the motor apparatus have hoeostasis. Constancy of the indices characterizing the physical condition of the motor system in the state of calm and during activity appears both over short periods of time (1-time investigation of the subject) and over long periods of time (a week, a month).

* Leningrad. Department of Psychology of the Leningrad State University.

V. Kennan emphasized the relativeness and dynamic nature of the /187
constancy of functions of the organism, since the level of constants with respect to the changeability of the external environment cannot be constant. Constancy of state has lower and upper limits, exceeding these limits disrupts the system or disrupts its viability, since the level of stimulation and reactiveness of the organs depend both on the biological properties and chemical composition of the internal environment. Therefore, the task of the mechanisms of control and regulation in living systems, on the one hand, is to maintain constancy, while on the other it is principally to alter it and adapt by changing the system from a state of calm to an active state (working).

A clear example of maintaining the constancy of functions is the state of calm. We emphasize that the state of calm is created by activation of the regulation mechanism, although in a certain period of the history of development of the physiological concepts concerning the vital activity of living systems, calm has been viewed as a passive state.

1. The State of Relative Calm

N. Ye. Vvedenskiy [1] for example, included calm in the inactive state and did not link it with the state of excitation, which follows from the system of sequentially developing reactions of the excitation system in response to increasing force of the stimulus, which was introduced by him: A. Calm..... B. Activity ..... C. Parabiosis.. .... D. The state of excitation.....

However, it was subsequently established that in a state of calm latent excitation can accumulate, and that therefore, calm is not a passive state. In connection with this, A.N. Magnitskiy [2] views calm as a state of excitation, while N.V. Yermakov [3] directly includes calm in the active state which, following I.P. Pavlov, is /188
understood by him to be a state that can be linked with either excitation or inhibition. N.V. Yermakov considers physiological calm to be a state of latent physiological activity which is expressed

through a changing relationship of latent excitation and latent inhibition. Calm, states the author, is a particular case of physiological activity.

N.V. Yermakov represented the entire course of the developing reactions in the following form: .....Excitation ..... Calm ..... Parabiosis ..... Activity .....

This evolution of the concepts concerning physiological calm was preceeded by a long history of struggle of the Soviet physiological school, particularly the Leningrad University School, against the concepts of foreign investigators who considered that the state of calm is an inactive state, equal to zero from the energetic standpoint. These concepts were one of the "pillars" which supported the theoretical construction of the "all or nothing" law. The struggle against the widespread propagation of this law throughout all physiological processes of reaction, begun and then continued for long years by Academician A.A. Ukhtomskiy [4] led to a situation in which the problem of the nature of physiological calm as an important independent function was first posed by the school of N. Ye. Vvedenskiy - A.A. Ukhtomskiy [5]. As A.A. Ukhtomskiy noted, prior to this the problem of calm had not been posed, or before, calm was traditionally considered a state that was "understandable of itself".

A.A. Ukhtomskiy emphasized the relativeness of dominating concepts concerning physiological calm. "In discussions of sleep," he wrote, "we usually consider sleep to be predominantly physiological calm, but have no other foundation for this than the sign that sleep brings 'rest' and renewal from excitment and work. On the basis of this sign, there is the same justification to say that normal sleep is activity especially directed toward processes of restoration and restitution in the tissues and organs used during wakefulness."

A.A. Ukhtomskiy notes that at the early stages of physio- and ontogenesis, the state of calm is nearly absent. This is due to the great dependence of the organism on the environment, due to its poor

individuality. The basal metabolism in the lower animals depends to a great extent on the on-going, immediate physiological conditions of the environment. Inasmuch as the external environment is variable, the organism is constantly forced to adapt to these changes by increasing the basal metabolic rate, with unceasing activity of the animal. The living beings that are relatively better individualized from the external environment can also sustain immobility, due to their higher organization.

A.A. Ukhtomskiy emphasized that physiological calm is not itself an obvious physiological state, but is the result of complex processing and organization of the processes of physiological activity. In this case, the capacity for maintaining calm is the greater, the more rapid and immediately the living system is capable of concluding excitation within itself, i.e., the higher its lability. This concept of A.A. Ukhtomskiy is based on facts found by N.V. Golikov, [6] who showed in 1933 that diminished inhibition corresponds to increased lability, and interpreted this state as physiological calm.

A.A. Ukhtomskiy distinguished two forms of physiological calm — a minimum of physiological activity, and operational calm of alert-guarded immobility (attention).

However, having advanced two types of physiological calm, he did not write whether the first type — the minimum of physiological activity — was inherent to the higher animals, including man. But this has great significance for understanding the problem of physiological calm. Does operational calm exist in man? If one views it as suppression of external activity, then can man always be in such a state? It is known that suppression of any reaction requires much greater effort than accomplishing the same reaction. This is an enormous nervous labor that can only be termed "calm" according to the external sign — according to the absence of external activity.

Therefore, it seems to us that one would be mistaken to imagine all human physiological calm to be operational calm. It is appropriate to remember in connection with this that N.V. Golikov distinguishes

"calm" and "operational calm": "A state of the tissue characterized by the presence of the anelectronic syndrome...we suggest terming it "the state of calm", or if this state is supported by stimuli, "the state of active (operational) calm". Ya.B. Lekhtman [7] also distinguishes the concepts of "calm" and "starting calm". He char- /190
acterizes the former as stability of functions, and the latter as mobilization of functions.

However, inasmuch as man daily encounters many facts of activity which can cause the appearance of pre-working states in him, and consequently their "operational calm", one can theoretically imagine that in the healthy person there will be no other states than various states of "operational calm" and the different activities.

At this point it should also be taken into account that familiar reactions not accompanied by a significant emotional background need not evoke a prolonged and pronounced pre-working state. It is most probable that in the initial state we remove the moderate background (and their consequences) from many states, but we seldom observe the pronounced pre-start reaction (operational calm), even under certain (adequate for the given activity) conditions.

Therefore, in a situation when man either is not thinking about the upcoming activity, or is not familiar with the activity, or if the activity has become automatic in him and does not evoke emotional pressures, one can observe the state of "pure" calm, without adjusting for the upcoming activity.

2. The Pre-working State of Calm ("Operational Calm" and the Psychic States Similar to it).

The transition period between the state of calm and the working state (accomplishing the action) is the pre-working state of adjustment to the activity, which has been variously termed among different authors. Even Eksner viewed the simple psychic reaction as a "preparatory reflex" with the period preceding intense

expectation of a stimulus. Ukhtomskiy termed the state of expectation (preparedness for activity) "operational calm".

The state of adjustment, studied in detail by D. N. Uznadze and his school (I.T. Dzhalava, [8] A.S. Prangishvili [9] et.al.) is near the state of "operational calm". In athletic psychology, it is known as the pre-start state (A.P. Puni). The French psychologist Le Ni /191 termed the special functional state created by verbal instructions concerning upcoming activity as the "latent stimulus of the reactive system". Finally, M.I. Vinogradov [10] links this state of preparedness with pre-start innervation.

What is this state?

In advancing the concept of operational calm, A.A. Ukhtomskiy understood it to be preparedness for action that can exist at different levels. The more highly organized the capacity for operational calm, moreover, the more highly organized the immediate preparedness for action will be.

Hence, A.A. Ukhtomskiy understood physiological calm to be an active energetic state (inasmuch as the active state also includes states that do not exhibit a visible manifestation). In this sense, operational calm is latent activity which exists so that clear activity can follow it (action).

In the opinion of A.A. Ukhtomskiy, operational calm is achieved by two pathways – by increasing lability, and by increasing the thresholds of excitation. In both cases, passive inactivity is not referred to, but special limitation of the act of excitation. This is suitable for us in the sense that we limit ourselves to external neutral (indifferent for us) stimuli. Thereby, a special selective excitation of our systems in response to certain external factors is ensured.

Notwithstanding the great interest shown the pre-working state, up to now it has contained a great deal that is unclear. It is most

necessary to clarify the role of pre-start factors. Many authors consider that adjustment (or the state similar to it but given another name) enables more rapid response to the starting signal. Le Ni, for example, considers that the stronger "latent excitation", the sooner it reaches the "threshold" level under the effect of the starting stimulus, and the shorter the latent periods of the corresponding reactions. F. Olport supports the same opinion on the role of adjustment in preparatory activity.

Actually, a number of experimental data confirm these opinions. It has been shown that the preliminary command shortens the latent period (Geblevichova). On the other hand, a signal that has suddenly appeared leads to an increase in the latent period (N.G. Levandovskiy /192 [11], R.Kh. Sishor [12], O.A. Konopkin [13].) But do adjustment or the state of operational calm or states similar to them appear only with respect to increasing the rapidity of human response? And is it impossible to link the pre-working state with the quality of reaction? In fact, adjustment is viewed as a mechanism of programming the upcoming activity (I.T. Bzhalava). Hence, the question as to how much the qualitative pre-working changes correspond to the qualitative characteristics of activity is important.

In the investigations of M.S. Bychkov [14], from B.G. Anan'yev's laboratory, the character of distribution of the biocurrents of the muscles of both arms, in imagining boxing, exactly corresponded to the experience of the boxer and the non-boxer, under similar conditions of activity: in the experienced boxer greater activity of the muscles was observed in the left arm, more active in boxing, while in the non-boxer greater activity was observed in the right arm, since he did not imagine himself boxing, but brawling.

In accordance with the assigned character of activity, the pre-working changes were also detected in one of our investigations. We measured the hardness of muscles in 37 school children and 17 adults prior to squeezing dynamometers with both hands (with the assignment to squeeze both dynamometers with the same force). At first, the hardness of the muscles was measured in the state of calm, and then

after the signal, "prepare to squeeze". After this signal, the hardness of the muscles increased in 75% of the cases among school children, and in 92% of the cases among adults. Here, in 83% of the cases of the investigated adults (men and women) and young people, a greater increase in hardness of the muscles occurred in the right (leading) hand, which proved to be stronger when squeezing the dynamometers. In girls, a greater change in muscular hardness occurred in the leading hand in 54% of the cases. This indicates that in most cases the established effects are stronger when coming from the leading center than when coming from the non-leading one.

Metfessel and Orren found that in many people, at the command for simultaneous movement of both hands, the left (non-leading) hand began to move earlier, and the authors explained this as supercompensation for the less-used hand during the attempt to carry out simultaneous movement. In a number of cases, we also observed something similar: upon the assignment to exert identical strength with both hands, the subjects (who were not left-handed) exerted greater strength with the left hand.

TABLE 1

/193

EXPRESSION OF THE ESTABLISHED REACTIONS (INCREASING THE HARDNESS OF MUSCLES) IN CASES OF GREATER ATTRACTION OF THE SUBJECT'S ATTENTION TO THE NON-LEADING HAND.

Hardness in the right hand (in arbitrary units)			Hardness in the left hand (in arbitrary units)			Dynamometer	
Initial	Before effort	Increment, %	Initial	Before effort	Increment, %	Right Hand	Left Hand
19.2	22.7	18.0	18.4	25.3	37.4	20.2	22.4

Investigation of the adjustment effects of the central nervous system on the hardness of muscles showed that this phenomenon is not a random one. In 8-11% of the cases, we found that the hardness of the muscles increased to a greater degree in the left (non-leading) hand and that during this process greater force was exerted by the subjects using the left hand, in an absolute majority of these cases. The data cited in Table 1 illustrate this.

Consequently, in the given case even the pre-start effects reflected the adjustment of the subject to exerting force with the left hand. The subjects themselves explained this in that, knowing the lag in strength of the left hand, they gave greater attention to this hand in order to equalize strength in both hands.

Proceeding from the cited data (our own and those of the literature), it would seem that one could speak of complete correspondence of the adjusting and starting effects of the central nervous system on the periphery and that the pre-start changes should always precede the start effects.

N.I. Chuprikova [15], for example, writes that "the pre-start changes in excitability are an extremely important, if not the decisive, element in bringing about the reaction according to preliminary instructions". It appears that without pre-start changes in excitability, reactions cannot occur. At the same time, everything is apparently more complex than this. In 34.6% of the cases the school children, in our investigation, were entirely lacking the conditioning reaction, while strength was still greater in the right hand. Adjustment reactions were absent in a number of cases (in 8-10%) among adults and young boys.

Consequently, a number of data (namely, the greater expression /194 of conditioned reactions: 1. in adults, as compared with children, and 2. in young boys in comparison with young girls), provide grounds to consider that the conditioned reactions in the form of redistribution of muscle tone are acquired together with motor skill in man, and have a conditioned-reflexive character. N.I. Chuprikova, on the basis of Ye.I. Os'makova's data, also hypothesizes that among young children the pre-start increase in excitation is less pronounced than among adults. At the same time, the pre-working changes are not always linked with cognizance and are not always subordinate to voluntary regulation. If there were cognizance and the capacity for voluntary regulation, we should have obtained a greater change in tone in the right hand, in comparison with the left hand, since the instructions required uniformity of strength in both hands.

The manifestation of functional asymmetry during start factors, without asymmetry in the pre-start changes in muscle tone in both hands, indicates that in certain situations, with respect to unconcious conditioning, the pre-start state is a mechanism that reinforces and accelerates the starting factors, but does not determine the result of action. Easing the manifestation of the start factors occurs due to the fact that adjustment, as Olport hypothesizes, is a structure closed within itself; preliminary muscle tension leads to the transmission of inhibiting proprioceptive impulses to the centers. Due to this, the threshold of the centers lowers, which eases the reception of information.

The degree of expression of the pre-working changes depends upon many factors: on the level of pretensions, on requirements for the given activity, on the estimate of the probability of achieving the goal, on individual-typological characteristics of personality (Yu.Ya. Kiselev [16]), and on the intensity of the upcoming activity (A.N. Krestovnikov [17]).

The question of over what period of time prior to the activity the appearance of operational calm is expedient is of particular interest. This period of time depends on many factors (the specifics of activity, motivation, stage of a given type of activity, sex, and even the development of intellect). Thus, according to the data of A.D. Ganyushkin [18], excitation appears in women more often, 2-3 days/195 before the start, (in 24% of the cases), than in men (in 7% of the cases). Among athletes with a better developed intellect, excitement appears more often 2-3 days before the start (35%) than among those having a mid-level or 8-year education (respectively, 13 and 10%). The authors link this with the fact that with the increase in intellect there is a significant improvement in the human capacity for predictive analysis. Finally, advanced athletes, as a rule, begin to get excited earlier before a competition than the less experienced ones.

To what extent does the change in the pre-working state favorably affect the total activity of man? It is obvious that a too early

appearance of the pre-start state leads to rapid exhaustion of the nervous potential and decreases psychological preparedness for the upcoming activity. All the same, it is difficult to give a definitive answer here, but for certain types of athletic activity an interval 1-2 hours prior to competitions is optimum.

A special question related to pre-working adjustment is concentration prior to carrying out an activity (A.P. Puni). Here, the given conclusive phase of psychological readiness for the activity should be used as a time for self-regulation of the state (for example, struggling with fear and lack of confidence, or, on the other hand, with wandering attention).

During concentration, the earlier-developed muscular-motor sensations are activated, as are the method of action and positive emotions; voluntary mobilization of the human capacities occurs. In this case, one can actually consider that the adjustments program the upcoming activity, which I.T. Bzhalava has written about.

The duration of the concentration phase cana depend on different factors. For example, the appearance of a sense of fear, which is combatted in the phase of concentration, depends on sex (fear occurs more frequently in women than in men), qualifications, experience, age, etc. (A.D. Ganyushkin and Ye.A. Kalinin [19], A.V. Romanin [20]). The complexity of the upcoming activity and its significance for man also have an effect (F. Genov [21], A.B. Livmane [22], G.I. Savenkov /196 [23], L.N. Radchenko [24], V.I. Silin [25-26]).

According to the data of A.B. Livmane, it is characteristic that during stable execution of actions, stability of the time of concentration is also observed — this comprises half of the time necessary for actually executing the exercise.

Obviously, there is an optimum time of concentration that is individual for each person.

3. The Significance of the Initial Background (State of Calm for

High Working Capacity).

What is homeostasis of the systems from the viewpoint of the theory of optimum control and regulation? How does it depend upon the property of homeostasis of the human working capacity? Is the state of calm a passive background against which the stimulus acts?

Ya. A. Egolinskiy views homeostasis with respect to the vegetative functions as the manifestation of preserving the optimum level of the constants that characterize the functional state of any system.

Ya.B. Lekhtman is near this view when he writes that one of the basic concepts of cybernetics – optimality– is characterized by functional stabilization in calm. But in what does this optimality of homeostasis consist? Neither author provides an answer to this nor cites evidence that in the initial period there can be an optimum state of calm of an organ or system. In order to clarify this, experimental data were acquired that would confirm the presence or absence of an optimum state of the system in calm.

Such data were obtained by us when studying the relationship of /197 weakening of the muscles and the value of the tone of calm. All cases were processed in which there was weakening of the muscles in keeping with the value of their tone in calm. It proved that the greatest degree of muscular weakening corresponds to moderate values of the tone of calm, within limits of the range in which the weakening reaction is observed (Table 2).

TABLE 2.
THE DEGREE OF WEAKENING OF THE MUSCLES AGAINST DIFFERENT INITIAL CALM TONES

	Initial values of tone (in arbitrary units)					
W/C*	56.0	58.7	57.3	60.4	64.6	more than 65
	0.96	0.955	0.955	0.931	0.944	0.954

* The index W/C stands for the relationship of the tone of weakening to the tone of calm (the smaller the index, the greater weakening of the muscles).

A study of the dependence of the latent period and the time of movement on the degree of muscle tension also shows the presence of optimum values of the initial state (calm), in which optimum reactions in response to the effect of an optimum stimulus occur most clearly (Table 3).

TABLE 3.

THE DEPENDENCE OF THE EXPRESSION OF OPTIMUM REACTION ON THE INITIAL VALUES OF THE LATENT PERIOD AND THE TIME OF MOVEMENT

index	initial values of the index (mean), msec	decrease in values of the index under the effect of muscle tension, %
latent period	212	9.2
	237	16.0
	260	11.0
time of movements	141	16.5
	172	24.4
	215	17.9

One can see from these data that tension of the muscles caused the greatest decrease in the latent period and time of movement when their values in the initial state were not too low or too high, but were at a mean (optimum) level. /198

Similar data were also found by other investigators. O.D. Yakimova [27] notes that high indices of the dynamometer correspond to the mean level of muscle tone. T.P. Fanagarskaya [28] found that the time of covering a distance is better at mean values of tone established after warm-up. At low and high values, running speed decreases.

A similar conclusion is also reached by P.A. Rudik with respect to the latter phase of pre-working adjustment — concentration. He hypothesizes that, inasmuch as the concentration of attention is "a dynamic process that develops from the initial moderate level of a given function to its necessary highest limiting state, with an unavoidable decrease in the intensity of the psychological process", it should be preceded by a "comfort zone" that corresponds to the concentration maximum in which the motor impulses are most successfully

expressed. P.A. Rudik [29] notes that the highest clarity and definition of the corresponding psychological functions are required so that the motor representatives are not of a contemplative character, but rather are ready to convert to action.

The pre-start increase in excitation should also be optimum in value, which is clearly seen in the so-called pre-start state, which is not only encountered among athletes, but among all people before an important activity (in artists, in students before examinations, etc.). It is known that excessive excitment (start-fear), just as is the case with an indifferent attitude to the upcoming activity, which has the result of over-excitement (start-apathy) does not permit man's manifestation of maximum working capacity. An optimum of pre-start excitement is required (A.P. Puni [30]).

Thus, the experimental data indicate the presence of an optimum-initial functional state of the motor apparatus in which the greatest working capacity appears. Inasmuch as the greatest working capacity is linked with the optimum working state of the motor apparatus, a link and dependence of the optimum working state with the optimum in calm of this system is detected. /199

What are the signs of the system in the state of calm? At present, we have experimentally succeeded in revealing only one sign: during the optimum state of calm, fluctuation is greatest (Table 4.).

TABLE 4.

FLUCTUATION IN THE LATENT PERIOD WITH DIFFERENT BACKGROUNDS OF THE STATE AND EFFECT OF MUSCULAR EXTENSION (DECREASE IN THE LATENT PERIOD).

value of latent period in initial state, msec	fluctuation in latent period in initial state, %	effect of tensing muscles (decrease in the latent period), %
21.2	38.8	9.8
23.7	41.5	16.0
26.0	32.9	11.0

Apparently, the isolated relationships between the fluctuations during calm and furing work have a general character, since A.G. Falaleyev [31] and S.K. Sarsaniya [32] demonstrated that the coefficient of variability in the duration of the cardiac and respiratory cycles is lower while a man is working than when he is resting.

One can also note stability of the optimum state of the motor system during calm, which follows from concepts concerning homeostasis.

* * *

In duscussing the question of the optimum state of calm and its significance for subsequent activity., we touched on the more general question of the significance of the initial background for the appearance of a reaction of any type. This does not only deal with the fact that during the optimum state of caom the most adequate reactions occur, and in the non-optimum state of calm the least adequate reactions, but also in the fact that during the non-optimum state of calm, reactions can appear that are inadequate for a given situation (inverted reactions).

Even in his first studies, I.M. Sechenov demonstrated that the /200
rapidity and strength of the reactions in vertebrates do not only depend on the characteristics of the stimulus, but also on the initial position of the animal's extremities. Facts similar to these were obtained by Magnusson and Sherrington, N.Ye. Vvedenskiy, and A.A. Ukhtomskiy in a joint study which showed that, in a single state of the system, stimulation can lead to excitation, while in another functional state, the same stimulus can lead to inhibition. This concept was subsequently developed by N.V. Golikov in his law on the lability optimum. Depending on the level of lability, the same stimulus can evoke either excitation or inhibition or tissue calm.

These facts were obtained in experiments performed on animals. We found similar data for man.

In one of the investigations, we encountered the fact that

occasionally even trained people are not in a state to weaken the muscles of their arms, i.e., lower the tone of the muscles in comparison with the state of calm (Ye.P. Il'in [33]). On the other hand, in place of a decrease in the value of tone, an increase in tone was observed in them i.e. an inverse reaction to the one we had expected. An analysis of these cases showed that such reactions are observed if the tone of calm is higher or lower than ordinarily.

TABLE 5.

DEPENDENCE OF THE TYPE OF REACTION DURING AN ATTEMPT TO WEAKEN THE MUSCLES ON THE INITIAL VALUES OF THE TONE OF CALM.

Tone of calm (in arbitrary units)	58.8	60.0	61.9	more than 62
type of reaction	inverse (increase in tone)	tone did not change	adequate (weakening)	inverted (increase in tone)

The massive investigations subsequently conducted confirmed the fact that in order to obtain the reaction of additional voluntary weakening of the muscles, mean values of the tone of calm are required. In the simplest form, this relationship can be seen in Table 5.

It should be noted that inverse reactions at a low tone of calm /201 are encountered several times more frequently than in the high tone of calm.

These data show that weakening of the muscles (the working effect of activity of the motor system) is only observed against a certain initial functional state of the motor system.

Of course, these data do not in any way indicate that any type of reaction during an attempt to weaken the muscles will be observed at these values of the tone of calm. They are mean data for all investigations and are cited by us for the purpose of illustrating that at low values of the tone of calm there are more chances of obtaining the inverse reaction than at mean values.

The relationship of any type of reaction and the initial functional state could be observed by us when studying the accuracy of movements in connection with various tempos of their execution (Ye. P. Il'in [34]).

The average data obtained for all subjects clearly show that the accuracy of movements under all conditions (different tempos) always strives to hold the constant (mean) value. In connection with this, it also turns out that with a large error in the initial condition, the shift in tempo leads to a decrease in error; with a mean value of error, the accuracy during the change in tempo does not change; but with a small error, a change in tempo leads to an increase in error. Inasmuch as the accuracy of movements in this case was an indicator of the original functional state of the motor system, we conclude that the working effect depends not only on the activity conditions (the tempo of movement in the given case), but also on the initial background of the beginning of this activity.

Inversion of the reactions appears in these experiments in that, instead of the expected effect of an increase or decrease in accuracy during the shift from a rapid tempo to a slow one and vice versa, we obtain an inverse picture. For example, if in the given subject the shift from the slow tempo to the fast tempo usually led to an increase in the accuracy of movements, (i.e., for this subject the rapid tempo was more optimum), then with high accuracy of movements in the initial state (prior to changing the tempo), the change in tempo caused an inverse reaction — an increase in error— and consequently a decrease in accuracy.

Finally, we encountered the effect of the initial background on /202 the type of motor system reaction when studying the effect of muscular tension on the value of the latent period and the time of movement (Il'in and Pauperova [35]). In a number of cases, one could observe inverted reactions that consisted of the following. Usually, in increasing tension of the forearm muscles to a certain degree, we observed a decrease in the value of the latent period and the time of movement. With an extreme extension of the time of the oculo-

motor reaction, there was also a new increase and even excess over the initial values (without tensing the muscles). Inversion of the indicated reaction corresponding to the law of the stimulus strength optimum consisted in that, instead of the expected decrease in the value of the indices, on the other hand, we obtained an increase in their value with moderate degrees of tension, but with a large degree of tension the latent period and the time of movement once again decreased. And once again, in a majority of cases, the cause of reaction inversion was low values of the studied indices in the initial state (prior to tension). Thus, in one case values of the latent period were within limits of 230-280 msec during normal reactions, but during inversions of the same reactions the latent period was 205-225 msec.

If one imagines a complete picture of the relationship of the value and type of reaction and the initial functional state of the working system, it will be as follows: at low initial values of the tone of calm, inverse reactions are observed. The lesser the tone, the greater the value of inversion; at mean values of the tone calm, an adequate reaction is observed (weakening of the muscles), and the degree of adequacy depends upon the values of the tone. At optimum values of weakening it is greatest, while a subsequent increase in tone causes a decrease in the degree of weakening, and at great values of tone, the inverted reactions can once again appear.

Thus, an important place in optimizing human activity should be attributed to the relationships of the optimum working state of the system with optimum state of calm.

This relationship is based on the general principle governing the dependence of the effect of the stimulus not only on the characteristics of the stimulus, but also on the initial functional state (background) against which the stimulation occurs. This question also has general and theoretical and practical significance.

The theoretical aspect of the question consists in the fact /203
that the "functional background" is viewed as a factor that is

wedged in between the signal and the reaction and to a great extent determines the fate of the reaction. The simplified approach to the relationship between the stimulus and the reaction that has existed since the time of Decartes and his mechanistic concepts concerning the reflex arc is thereby negated. The "stimulus-reaction" principle has been supported by foreign psychologists of the old school in the form of the "hypothesis of immediacy", according to which the outer world acts and alters the human psyche directly, without the participation of the organism as a physical entity. According to the same concepts, man is ignored as a subject.

Today, in connection with the development of cybernetics, and in a number of cases with the simplified approach to simulating human functions, it is important to emphasize the unfitness of former concepts concerning the simple relationship of cause and effect, stimulus and reaction. The change in views on this question has also been reflected in philosophical concepts of cybernetics. Thus, G. Klaus [36] considers goal-directed activity such that various factors produce the same consequence. But in his system, there is no direct relationship between cause and effect. Between the two stands the organism with its experience, in accordance with which it directs the formation of the goal-directed response reaction. If the cause does not evoke the planned effect according to the system, the organism makes a correction (according to the feedback system) in the flow of information. Of course, the Klaus system does not answer the question of what the role of the organism is and how the achievement of the necessary result occurs, but it is important to us as an illustration of changes in concepts concerning the relationship between stimulus and reaction.

The significance of the intermediate element between stimulus and reaction is emphasized today by many authors. Thus, E. Tolmen mentions "terminal readiness", i.e., a state acquired as the result of conditioning or education, maintained in the organism, and expressed in the form of expectation in the case of actualization.

American psychologists speak in this regard concerning inhibited

reactions of the expectation type (D. Hebb), which are similar to the concepts of A.A. Ukhtomskiy on operational calm. Psychologists concepts concerning adjustment as preparedness for the development of activity of a certain type are widespread both in the Soviet Union and abroad. Finally, the concepts of P.K. Anokhin [37], N.A. /204 Bernshtein [38], and F.B. Bassin [39] also indicate that the organism's reaction is formed taking into account the inner state of the organism (the next part of this study will discuss concepts of these authors concerning the mechanisms of reaction formation).

Hence, the question we touched on in this article has an important theoretical result that pertains not only to calm as the initial background wedged between the stimulus and the reaction, but also to the problem of forming the goal-directed behavioral acts, taking into account the mechanisms of foresight and adjustment, etc.

The second aspect of these questions pertains to the practical use of the obtained acts. Up to now, in the psychological literature (a survey of which was provided in the study of B.F. Lomov [40]), when the subject comes to the conditions of operator labor, one aspect of the question is primarily discussed – the optimum characteristics of signals. Optimum zones of stimuli are isolated in which the stimuli are adequately preceived by the analyzers. Within the limits of this large range of stimuli are the operational thresholds, i.e., the optimum values which ensure best differentiation of signals (M.A. Dmitriyeva [41], B.F. Lomov [42], P.M. Fitts [43], V.M. Vodlozerov [44]). Another aspect of the question in the "man-machine" system is the functional state of the operator - the initial background against which the signals are perceived frequently remains outside the field of vision. In the meantime, George K. Stephens and S.S. Stephens suggest introducing the concept of the "Physiological Zero" for considering the initial state, i.e., taking into account the absolute threshold of sensitivity under the given conditions, applicable to which one should estimate the intensity of the active stimulus.

There is also the concept of the physiological strength of the /205

stimulus, which takes into account not only the physical value of the stimulus, but also its significance for the organism. The latter is to a significant degree determined by the initial state.

Hence, it obviously follows that in finding the factors that determine the optimum working state of man, one should proceed from the fact that the working effect of the "man-machine" system depends both on the external conditions (the value of signals evoking the responsive motor reactions, the parameters of movements during manipulations with the control organs), and on the internal state of man, which is due to many factors (morphophysiological characteristics, age and sex differences, level of training, and finally, fluctuation in the functional state in microintervals of time). Therefore, the choice of any optimum value of a signal or parameter of movement should be made taking into account the functional state of man. Inasmuch as the effect of human activity is determined by the factors indicated above, the problem of assigning this to a system (stimulus-human action) of constant correspondence of stimulus value to the functional state of the motor system arises. Of course, man as an autostimulating system is more labile in comparison with the technical devices which he deals with, and therefore it would seem that primary attention should be paid to "regulating man". During this process, however, it should be borne in mind that any living system including man has a threshold of "regulation" (bringing his functional state into accordance with the stimulus received from the control panel), and on the other hand, "regulation" of living systems itself is a quite fine and complex matter (we only recall the great difficulties in selecting the optimum load when warming up athletes before a competition). Therefore, it seems to us that one should also not forget another pathway – the possibility of the operator's obtaining such signals or the capacity to manipulate the control organs from the control panel in the case of parameters of motion that are "convenient" at a given moment. It is easy to achieve this if the operator has the capacity to change, for example, the brightness of a signal or the loudness of a sound, or to change the parameters of movement at will.

It is entirely obvious that the "man-machine" system (including the industrial environment in which man works) should be dynamic. /206 This dynamic nature should be due not only to a change in the functional state of man, but also to a change in the external conditions of activity in accordance with his state (taking into account periods of tiredness and fatigue, and not only the period of stable working capacity). Other investigators who have studied facilities that maintain the attention of man at a high level have also come to this conclusion. Thus, Lepla and Makvorts consider that under conditions of monotonous operation of signals one should increase the amount of information reaching man.

Of course, the choice of an optimum signal or load for a given moment is a difficult matter and requires objective and continuous control over the state of the working man. Here, such control should not so much fix disruptions in the state as predict these disruptions. Naturally, without criteria of the optimum state it is difficult to accomplish this task. Isolating these criteria makes it possible quite accurately to judge human working capacity at the moment of observation and in the future (if the first signs of deviation from the optimum state are noted).

Great aid in controlling the state of man should be given by technical devices that can give the operator information on his state on the control board at the necessary moment, and even automatically regulate the flow of information coming to him, taking into account his state. These devices could develop recommendations concerning the optimum pathways of voluntary regulation of states, i.e., aid man in accomplishing self-optimization (B.F. Lomov and A.I. Prokhorov [45]). The necessity of constantly controlling man's state is particularly acutely sensed in connection with the development of astronautics (I.T. Akulinichev, R.M. Bayevskiy [45], V.G. Denisov, A.P. Kuz'minkov, V.I. Shayev-Yazdovskiy). The first steps are already being taken in this direction (Levi, Johnson, R.S. Dadashev, V.B. Malkin [47], S.T. Khlebikov), and one can hope for their successful resolution.

REFERENCES

1. Vvedenskiy, N.Ye. Vozbuzhdeniye, tormozheniye i narkoz. (Excitation, Inhibition, and Narcosis.) St. Petersburg, 1901

2. Magnitskiy, A.N. Uspekhi sovremennoy biologii. Vol. 26, 1948, p. 875.

3. Yermakov, N.V. Uspekhi sovremennoy biologii, Vol. 33, No. 2, 1952, p. 218.

4. Ukhtomskiy, A.A. Uchenyye Zapiski LGU, Vol. 17, 1937, p. 213.

5. Vvedenskiy, N.Ye. and A.A. Ukhtomskiy. Raboty fiziologicheskoy laboratorii (Works of the Physiological Laboratory of St. Petersburg University), 1909, p. 143.

6. Golikov, N.V. Fiziologicheskaya labil'nost' i yeye izmeneniya pri osnovnykh nervnykh protesessakh. (Physiological Lability and its Changes during the Basic Neural Processes.) Izdatel' stvo LGU, 1950.

7. Lekhtman, Ya.B. Materialy VIII nauchnoy konferentsii po voprosam morfologii, fiziologii i biologii myshechnoy deyatel'nosti. (Materials of the 8th Scientific Conference on Problems of the Morphology, Physiology and Biology of Muscular Activity.) Moscow, 1954, p. 153.

8. Dzhalava, I.T. Psikhologiya ustanovki i kibernetika. (The Psychology of Adjustment and Cybernetics.) Moscow, "Nauka", 1966.

9. Prangishvili, A.S. Issledovaniya po psikhologii ustanovki. (Investigations on the Psychology of Adjustment.) Tbilisi "Metsniyereba", 1967.

10. Vinogradov, M.I. Fiziologiya trudovykh protsessov. (The Physiology of Labor Processes.) Izdatel'stvo LGU, 1953.

11. Levandovskiy, N.G. Materialy konferentsii po metodam fiziologicheskikh issledovaniy cheloveka. (Materials of a Conference on Methods of Physiological Investigations of Man.) Moscow, 1962, p. 110.

12. Sishor, R.Kh. Work and its Motor Execution. In the book: Eksperimental 'naya psikhologiya. (Experimental Psychology.) Vol. 2, Moscow, Foreign Literature Publishing House (IL). 1963.

13. Konopkin, O.A. "Voprosy psikhologii", Vol. 1, 1964, p. 45.

14. Bychkov, M.S. "Uchenyye zapiski LGU', Seriya Nauk. Byp. No. 4, 1953, p. 83.

15. Chuprikova, N.I. Slovo kak faktor upravleniya v vysshey nervnoy deyatel'nosti. (The Word as a Control Factor in Higher Nervous Activity.) Moscow, "Prosveshcheniye", 1967.

16. Kiselev, Yu.Ya. Tezisy dokladov rasshirennoy nauchnoy konferentsii kafedry psikhologii, posvyashchennoy 70-letiyu prof. A.P. Puni. (Abstracts of Reports of an Expanded Scientific Conference of the Department of Psychology Devoted to the 70th Birthday of Professor A.P. Puni.) Leningrad, Gdolifk im. P.F. Lesgafta, 1968, p. 28.

17. Krestovnikov, A.N. Ocherki po fiziologii yprazhneniy. (Aspects of the Physiology of Exercise.) Izdatel'stvo FiS, 1951.

18. Ganyushkin, A.D. Tezisy dokladov rasshirennoy nauchnoy konferentsii kafedry psikhologii, posvyashchennoy 70-letiyu prof. A.P. Puni. (Abstracts of Reports of an Expanded Scientific Conference of the Department of Psychology Devoted to the 70th Birthday of Professor A.P. Puni.) Leningrad, Gdolifk im. P.F. Lesgafta, 1968, p. 7.

19. Ganyushkin, A.D. and Ye.A. Kalinin, Ibid, p. 10.

20. Romanin, A.V. Psikhologicheskaya podgotovka sportsmenov razlichnykh vidov sporta k sorevnovaniyam. (Psychological Preparation of Athletes of Different Sports for Competitions.) Izdatel'stvo FiS, 1968, p. 162.

21. Genov, F. Tretiy vsesoyuznyy S'yezd obshchestva psikhologov. (The 3rd All-Union Congress of the Society of Psychologists.) Abstracts of Reports, Vol. 3, No. 2, Moscow, 1968, p. 30.

22. Livmane, A.B. Tezisy dokladov rasshirennoy nauchnoy konferentsii kafedry psikhologii, posvyashchennoy 70-letiyu prof. A.P. Puni. (Abstracts of Reports of an Expanded Scientific Conference of the Department of Psychology Devoted to the 70th Birthday of Professor A.P. Puni.) Leningrad, Gdolifk im. P.F. Lesgafta, 1968, p. 33.

23. Savenkov, G.I. Ibid, p. 91.

24. Radchenko, L.N. Ibid, p. 68.

25. Silin, V.I. Ibid, p. 76.

26. Silin, V.I. Ibid, p. 76.

27. Yakimova, O.D. Materialy VIII nauchnoy konferentsii po voprosam morfologii, fiziologii i biologii myshechnoy deyatel'nosti. (Materials of the 8th Scientific Conference on Problems of the Morphology, Physiology and Biology of Muscular Acitivty.) Moscow, 1964, p. 296.

28. Fanagarskaya, T.P. Kliniko-fiziologicheskiye metody issledovaniya sportsmenov. (Clinical-Physiological Methods of Investigating Athletes.) Izdatel'stvo FiS, 1958, p. 209.

29. Rudik, P.A. Ibid, p. 3.

30. Puni, A.P., "Teoriya i praktika fizicheskoy kul'tury" (The Theory and Practice of Physical Culture.) 1949, p. 7.

31. Falaleyev, A.G. Materialy VIII nauchnoy konferentsii po voprosam morfologii, fiziologii i biologii myshechnoy deyatel'nosti. (Materials of the 8th Scientific Conference on Problems of the Morphology, Physiology and Biology of Muscular Activity.) Moscow, 1964, p. 261.

32. Sarsaniya, S.K. Materialy VIII nauchnoy konferentsii po voprosam morfologii, fiziologii i biologii myshechnoy deyatel'nosti. (Materials of the 9th Scientific Conference on Problems of the Morphology, Physiology and Biology of Muscular Activity.) Moscow, Vol. 3, 1966, p. 22.

33. Il'in, Ye.P. Electrophysiological Investigations of the Motor Apparatus, Trudy LSGMI, Vol. 64, 1961, p. 21.

34. Il'in, Ye.P. and G.P. Pauperova. Teoriya i praktika fizicheskoy kul'tury. (The Theory and Practice of Physical Culture.) Vol. 3, 1957.

35. Il'in, Ye.P. and G.P. Pauperova. Ibid, p. 45.

36. Klaus, G. Kibernetika i filosofiya. (Cybernetics and Philosophy.) Moscow, 1963.

37. Anokhin, P.K. Biologicheskiye aspekty kibernetiki. (Biological aspects of Cybernetics.) Moscow, Izdatel'stvo AN SSSR, 1962, p. 74.

38. Bernshteyn, N.A. "Problemy kibernetiki", No. 6, 1961, p. 142.

39. Bassin, F.B. Filosofskiye voprosy fiziologii vysshey nervnoy deyatel'nosti i psikhologii. (Philosophical Problems of Physiology of the Higher Nervous Activity and Psychology.) Moscow, Izdatelstvo AN SSSR, 1963.

40. Lomov, B.F. In the collection: XV mezhdunarodnyy s'yezd prikladnoy psikhologii. (The 15th International Congress of Applied Psychology), Lyublyana, 1964.

41. Dmitriyeva, M.A. Problemy inzhenernoy psikhologii. (Problems of Engineering Psychology.) Leningrad, 1964, p. 75.

42. Lomov, B.F. Chelovek i tekhnika. (Man and Technology.) Moscow, "Sovet-skoye radio", 1966.

43. Fitts, Pol'M. Engineering Psychology in the Design of Machines. In the book: Eksperimental'naya psikhologiya (Engineering Psychology), Vol. 2

44. Vodloverov, V.M. Materialy IV nauchnoy konferentsii po fiziologii truda. (Materials of the IV Scientific Conference on the Physiology of Labor.) Leningrad, 1963, p. 63.

45. Lomov, B.F. and A.I. Prokhorov. K voprosu o kontrole za sostoyaniyem cheloveka-operatora, (The Problem of Controlling the State of the Human Operator.) Izdatel'stvo MTO, RE im. A.S. Popova. 1965.

46. Akulinichev, I.T. and R.M. Bayevskiy. "Vestnik AMN SSSR, No. 2, 1964.

47. Dadashev, R.S. and V.B. Malkin. Biologicheskaya i meditsinskaya elektronika. No. 3, 1963.

N75 17954

ATTENTION AND ITS ROLE IN THE OPERATOR'S WORK

O.P. Shvetsov*

/207

Attention is an extremely complex psychological phenomenon that is not an independent psychological process, as opposed to perception, thinking, memory, emotions, and sensations, or will.

In the light of modern concepts, attention is a "form of organization of human psychological activity that is manifested in its directiveness, concentration, and relative stability". [1] This definition contains the basic characteristics of attention. Each of them characterizes significantly vital aspects of attention. Excluding only one of these properties would lead to the disappearance of the phenomenon called attention. Additionally, the psychological characterization of attention also contains a number of its other qualities, for example, distribution, redirection, etc, which are derivatives of the earlier-mentioned basic properties of attention. Thus, redirection of attention is a change in its direction, and in fluctuations in attention a change in its relative stability is expressed; the distribution of attention is also a voluntary property with respect to concentration. It can be understood as a simultaneous concentration on two or more different objects and forms of activity related to them.

In interpreting attention as a form of organization of human psychological activity, it becomes possible for us more deeply to provide a foundation for characterizing its basic properties and characteristics, and during this process to introduce sequentially the basic tenants of the teaching of I.P. Pavlov concerning the foci of excitation and the teachings of A.A. Ukhtomskiy of the dominant. During an examination of the basic properties of attention, concentration is primarily indicated. The physiological basis of concen-

---

*Kiev, Institute of Psychology of the UkSSR

tration is reinforcement of stimuli in the dominant focus accompanied by inhibition of the entire remaining portion of the cerebral cortex. The focus of optimum stimulation in the central nervous system is semmingly a point of attraction for stimuli moving from the other stimulated surfaces. [2]

Concentration occurs according to the laws of negative induction, due to which concentration on a single stimulus excludes the effect of other secondary, but simultaneously acting stimuli. Hence, concentration of the stimulus in the dominant focus coupled with inhibition of the upper regions of the nervous system is the physiological basis of concentration of attention.

A significant property of attention is its directivity. This property also derives from the conditions of formation of foci of optimum stimulation and the dominant. According to I.P. Pavlov, the relative intensity of the neural process determines the direction of neurostimulation, and the connection of agents with different action, while the direction of the stimulus is determined by the relative strength of those centers that interact. Hence, the teachings of Pavlov concerning the foci of optimum stimulation directly indicate that the directivity of the reflected activity expressed in the relationship of environmental agents with various actions of the organism depends on the direction of the neural process, that determines, in its turn, the relative strength of stimulation of those neural formations of the cerebral cortex that interact at a given moment. Similar thoughts are developed by A.A. Ukhtomskiy. "The state of the dominant", he writes, "is reinforcing and revealing the available proportions of central stimuli...In this regard, it in fact leads to execution in the form of a mechanism with a certain directivity of actions (with a simultaneous vector), that was prepared in the directly preceding mements, even though there is a little-determined relationship of stimuli in the centers." [3]

Hence, the directivity of attention has as its physiological /207
basis principles of lability and interaction of the basic nerve processes.

A knowledge of the laws of formation and functioning of the foci of optimum stimulation aid us in correctly understanding still another significant property of attention – namely, its stability. One of the signs of the dominant is the stability of stimulation, i.e., the stimulation begun in the dominant focus has a property to maintain itself and to be established over a certain period of time, which is expressed in the relative stabilization of psychological activity. "The characteristic aspect of the dominant," wrote A.A. Ukhtomskiy, "is its inertia: once evoked, a dominant is capable of firmly maintaining itself in the centers for a certain period of time, even after the stimulus that evoked it has been removed." [4] He also related an inclination to renewal according to the trace-effect during the repeated action of a stimulus that once evoked it to dominant inertia. These two signs of the dominant also lie at the basis of the relative stability of attention. First, this property is expressed in the presence of a certain stability of psychological processes that have once arisen and, second, in a continuation of them by inertia under conditions of cessation of the effect of the stimuli that evoked these processes as the result of other subdominant stimuli. Relative stability emerges as one of the most significant properties of attention.

Consequently, such properties of attention as concentration, directivity, and relative stability are the basic ones.

Proceding from the theoretical concepts presented above and pertaining to the essence of attention, we have also undertaken our own experimental investigation of the operator's attention in order to demonstrate the actual capacity of its improvement in the process of goal-directed education and training.

It is known that the professional activity of the operator makes high demands on his attention, which is one of the most important properties determining his occupational suitability. The decisive role of this personal quality is most clearly expressed in those types of operator activities that require simultaneous execution of different actions in very short periods of time. Therefore, when training

operators, it is vital comprehensibly to develop and to improve their capacity to concentrate, distribute and redirect attention, since it /210 is mainly these properties that greatly determine the success of solving the problems assigned them.

The capacity to be attentive is a stable characterological characteristic of man that is expressed in improving the organization of his activity, and is a vital condition for successfully accomplishing his labor function. The attentiveness of the operator should be studied, taking into account the requirements made on him by the specific type of occupational activity.

Of the different properties, the occupationally most significant for the operator are concentration, distribution, and redirection of attention.

The concentration of attention is a quality that is manifested in greater or lesser depth in activity. The greater the concentration of attention, the more productive the work accomplished will be.

The distribution of attention is characterized by simultaneous human execution of two or more types of activity and is achieved by adequately mastering certain components of work and methods of its execution.

Redirection of attention is accomplished by a planned change on the part of a man in the directivity of his activity. For the operator, this quality is especially important during emergency situations, changes in the operating regime of components, or in the process as a whole.

It is known that the distribution of attention depends on a number of conditions, primarily on how related the different objects and degrees of automation of action (to which attention must be distributed) are. The more intimately related the objects and the higher the degree of automation, the easier it is to distribute attention. The degree of redirection of attention differs among

different people: some do this easily and rapidly; in others "going to" another job requires a more or less long period of time and significant effort. The ease or difficulty of redirecting attention depends on a number of conditions. They include the relationship between the content of the preceding and upcoming activity and the attitude of the subject to each of them: the more interesting the preceding and less interesting the upcoming activity, then obviously, the more difficult it is to redirect attention, and vice versa. Therefore, absentmindedness in the common sense of the word is predominantly the result of poor redirectability.

An example of labor activity making extremely high demands on /211
human attention is the work of the pilot. Control of the aircraft is one of the types of operator activity that primarily includes goal-directed and continuous observation, in the process of which observation of the instrument panel, objects of ground orientation, and objects, radar station signals, and other sources of information is carried out. Simultaneously, the pilot must also carry out other important functions: he must analyze and evaluate the obtained information, plan a program of upcoming action in accordance with the mission assigned him, and finally, he must accomplish and control motor actions directly related to controlling the aircraft.

The successful accomplishment of all of these components of flight activity requires of the pilot broad distribution and timely redirection of attention. Requirements for these qualities greatly increase when flying at supersonic speeds, where the pilot must simultaneously or sequentially carry out several different kinds of actions in very short periods of time. Particularly high demands on attention are made in the period of flight training, when the pilot has not yet developed many of the professional skills and sensory-motor skills enabling him to carry out the necessary actions with minimum participation of consciousness, i.e., automatically. In the meantime, the practice of flight training as well as special psychological investigations indicate that in certain people the capacity to distribute and redirect attention does not always correspond to the high demands made on the person by modern aviation

equipment. Thus, for example, in an analysis of the causes of dismissal of cadets from flying schools which was carried out during World War II by the Agency of Psychological Investigation of the United States Air Force, it was found that 70% of all those dismissed for failure in the initial flight training course were observed to have significant and persistant shortcomings in the capacity to be alert and observant, specifically in the capacity to distribute their attention.

One of the important requirements made on the driving occupations is the extensive capacity to distribute attention and rapidly redirect attention. This is determined by the extensive and important multifaceted nature of factors of the outside world that determine success in controlling transport facilities.

The pilot-instructor must have an extremely extensive distribu- /212
tion of attention. In teaching the cadet to land, he must practically in a moment determine the distance to the ground, the pitch of the aircraft, the direction of landing, the situation on the runway, the operation of the engines by ear and the character of movements of the cadet; he must, inasmuch as possible, not intervene in controlling the aircraft, ensure flight safety, and simultaneously evaluate and remind the student of behavior characteristics. In the practice of training pilots at air clubs, training diagrams for distributing attention have long been employed in the most difficult flight elements. On these diagrams, the cadet draws simultaneously and sequentially the action carried out by him, using lines of different thickness: the thicker the line, the more intensive attention must be. This method could also be imployed in other types of occupational training.

Certain characteristics of attention distribution among power-loom textile workers were studied by A.P. Gozova (1957), who demonstrated that the distribution of attention among textile workers can be involuntary, voluntary, or post-voluntary. Involuntary distribution of attention appears as the result of the direct effect of an external stimulus. During the active forms of attention distribution

voluntary organization of labor actions occurs that requires significant exertions of will. Proportional to acquiring work skills on certain textile machinery, attention becomes post-voluntary and its distribution does not require efforts of will. The mastery of post-voluntary distribution of attention positively affects the labor productivity of textile workers. Thus, in the investigations of the above-named author, it was shown that the productivity of labor in textile workers increased by 10%, on the average.

A.A. Makogonova studied the distribution of attention among radio operators. She demonstrated that timely and rapid distribution of attention plays a decisive role in the activity of radio operators who had to receive signals by ear and then write them out in letters. When teaching reception and recording of radiograms, the radio operator must constantly distribute his attention among several stimuli, and the speed and productivity of his activity depends on the level of its automation and the personal activity of the radio operator.

A study of the distribution of attention in different types of occupational activity has shown that it can be achieved on the basis of participation of different mechanisms. The first and basic mechanism of the distribution of attention is accomplishing one or several/213 more or less automatic actions as the result of action of the "non-creative" centers. Earlier voluntary action became automatic and could accompany new actions carried out as the result of activation of the "creative" centers. "It is hardly an unusual thing," wrote I.P. Pavlov, "that we, in primarily being concerned with one thing, one thought, can simultaneously do another thing that is very familiar to us, i.e., work with those portions of the hemispheres that are to a known degree inhibited according to the mechanism of external inhibition, since the point of the hemisphere linked with our primary interest, of course, is then strongly stimulated." [5]

In a number of cases, that which seems on the surface to be distribution of attention is actually juxtaposition of a number of earlier independent actions into a new integral, unitary whole that externally is more reminescent of earlier independent actions. As

the works of V.V. Chebysheva and Ye.V. Gur'yanov demonstrated, this is the most typical pathway of acquiring occupational skill when attention is only distributed among derivatives of the created system of action. Thus, V.V. Chebyskeva demonstrated in a specially organized experiment that three techniques which garment cutters initially accomplish with redirection of attention over an average of 1.5 seconds are carried out by better workers as a single method over 0.2 seconds.

The act of attention distribution is often replaced and is usually supplemented by rapid redirection, and the boundary between them is practically never detectable. In this regard, particular interest attaches to the works of K.K. Platonov and A.A. Topornina (1951), who succeeded in demonstrating the transition of attention distribution to redirection in a special experiment. The investigation was carried out using an original device consisting of an electrical tachystoscope connected by four switches to four electrically operated stop watches. In the first series, red and blue cards were shown bearing colorless figures — a circle and a square — to each of which the subject was supposed to react by pressing a certain switch. In the second series, the four cards were shown in the opposite fashion, in the third and basic series, colored figures were shown and the subject was supposed to react simultaneously by pressing two switches, one for color and one for shape. It proved that at first the subjects either reacted in turn to color and shape (or vice versa), or reacted, even though simultaneously, with /214 a significantly greater reaction time than in the second series. In both cases, redirection of attention occurred: in the first — clearly defined, in the second — concealed. However, from the first investigations simultaneous reactions frequently appeared in which their reaction times were equal to the reactions of the second series.

After several tests, such reactions in which distribution of attention had occurred became more frequent. One can point out a number of criteria according to which one can successfully and with complete reliability establish the presence of redirection and not distribution of attention in studying occupational activity. However, the most

significant psychological criterion for the presence of redirection of attention is the appearance of a new goal of activity, transition from one action to another, or transition to a new method or new operation. Thus, a textile worker who operates many different machines in the textile industry widely distributes attention in observing all the machines; a thread break forces her to redirect her attention and concentrate it (very briefly) on elimnating the break, and then once again to redirect attention to the machines. A telephone operator, having said "ready!", redirects attention to another subscriber. An instructor in an aviation club redirects his attention several hundred times during the 4 minutes from take-off to landing an aircraft.

Delay in redirecting attention in all of the cited examples leads to a decrease in the quality of work, or sometimes to waste or an accident. But these examples illustrate only one of the two significant types of redirection of attention in the process of labor activity — the type of momentary restructuring of short-term activity. Another type of attention redirection in the process of labor activity is characterized not so much by rapid restructuring of attention as by deep restructuring of it during the transition to a new stage of work.

The physiological mechanism responsible for delays in redirecting attention and for the appearance of erroneous actions caused by perseveration (i.e., involuntary repetition) is inertia of the basic neural processes and the appearance of stagnant foci of stimulation in the cerebral cortex.

The principles of redirection and distribution of attention in the activity of the operator have been clearly inadequately studied, although these questions have been dealt with in a number of studies. Thus, in a study by T.Kh. Gurvich [6] the characteristics of attention distribution depending on the development of a motor skill in controlling several parameters are explained. In the investigation of N.K. Yoselian and A.L. Narinskaya [7], attention stability and the attention redirection capacity were studied using vacationing students

at the Air Force Flying School and the material of "blank" methods (seeking numbers with a shift, the red-black table, the correction method, "numerical complexation switch", etc.). However, a study /215
of the characteristics of attention in this investigation was carried out under conditions that did not simulate the activity of the operator. Therefore, the conclusions drawn by the authors require verification and additional checking.

1. The Task and Method of Investigation

A psychological analysis of the activity of the operator was carried out by the author and Ye.A. Mileryan [8] and enabled us to note the general structure of this activity, and, with respect to this, to determine the particularly important role of concentration, redirection, and distribution of attention during man's accomplishment of functions of active, goal-directed effort, in the process of which perception, selection, analysis, summarization and interpretation of on-going information were carried out and in which an adequate concept of the condition and tendencies of the further course of events in the system controlled by the subjects is created. The capacity to observe, actively follow, analyze, and summarize data characterizing the course of production processes must include a manifestation of the organization of human psychological activity in timely distribution, adequate redirection, and reliable concentration of attention.

In connection with this, it becomes naturally necessary psychologically to study the complex picture of dynamic interaction of concentration, distribution and redirection of attention, which characterizes the operator's accomplishment of his observation function.

This is why we set as our task an experimental investigation of the operator's attention while he is working in the observer mode.

The main goal of this study was primarily to clarify the requirements made by this mode on distribution, redirection and concentration /216

of the operator's attention, and second, to reveal the general psychological principles of improving these properties of attention in the learning process.

The investigation was carried out by the aid of the attentiometric method developed by Ye.A. Mileryan with the author's participation. The method was constructed on the basis of observing the principles of training and development, simulating the operator's activity, calculating the results and optimizing the conditions of testing.

The method described below is designed to test the operator's capacity to concentrate, distribute and redirect his attention under conditions simulating work on a control panel in the mode of continuous and discrete observation. The investigations were carried out on a specially constructed device — the Ye.A. Mileryan attentiometer.

On the front of the attentiometer, turned toward the subject, is an instrument panel below which is mounted the control panel. The instrument panel contains 4 arrow-needle meters, 2 pulse counters, and 2 indicator lights. Here too, on the upper portion of the panel, is a window through which the subject sees an aircraft model that changes its position. Below the window, on the control panel, is a level by whose use the position of the model can be corrected. The control panel contains 2 buttons designed to turn off the indicator lights, as well as 4 potentiometer controls that control the arrow-needles of the meters; ay turning these controls in a direction opposite of the direction arrows, the latter return to the zero position. On the same control panel are 2 buttons designed to stop the arrow of the pulse counters.

The examiner's control panel is located on the rear side of the attentiometer. It contains 3 arrow-needle meters, one of which fixes the total time of program presentation, the second regulates the time of observation (i.e., the time the aircraft model is held in the normal position), while the third calculates the number of errors made by the student during his work with the metered instru-

ments and the indicator lights. The errors are recorded if the subject is unable to turn off the indicator lights over the course of the programed interval of time, or to return the arrows to the zero position; the second of these tasks is considered accomplished only if the error of the arrow settings does not exceed one division of /217 the scale.

Besides the counters, the experimentor's control panel contains a lever to change the tempo of program presentation, buttons for starting and stopping the program and a button with an indicator of program return to the initial position. The electromechanical circuit of the instrument provides automatic provides automatic programmed lighting of the indicator lights, removal of the arrows of the pulse counters from the zero position, movement of the dial arrows and the aircraft model, as well as automatic stopping of the apparatus at the end of program presentation; the program consists of 26 separate problems.

During work on the attentiometer, the subject must continuously correct the position of the aircraft model, acting with his right hand, keeping the model in the normal position. He must simultaneously follow the lights, counters, and dials, and acting with his left hand, turn off the lights and return the arrows of the instruments to the zero position in a timely fashion.

Hence, the program of tests on the attentiometer forces the operator to accomplish several actions simultaneously: continuous observation of the position of the aircraft, discrete observation of the readings of the instruments, and returning all systems to the initial position. The successful solution of these problems primarily results from a capacity to redirect attention and distribute attention in a timely fashion.

In undertaking the complex investigation of concentration, distribution, and redirection of attention, we had to find objective criteria we could use to characterize each of these properties.

Psychological analysis of the structure of activity in the mode of observation showed that notwithstanding the fact that in the process of carrying out the functions of the operator, the properties of attention of interest to us are expressed in close interrelationship and interaction, there is still a real possibility of experimentally studying each of the properties separately. Taking into account the fact that when correcting the position of the aircraft model the leading property of attention is concentration on the object of observation, we hypothesized that the objective criterion of concentrating attention can be the coefficient of observation — C_{ob}. The latter is calculated according to the formula $C_{ob} = \frac{t}{T}$, where t-time of observation, i.e., time of keeping the aircraft in the normal position, T-total time of program presentation. /218

The objective indicator of the degree of distributing attention was the total number of omissions and errors made by the subject during reactions to the readings of the dials and lighting of the signal lights. The success of observing several objects primarily depends on timely distribution of attention.

The objective indicator of attention redirection was the number of errors made by the subjects upon stopping the rotating arrows of the pulse counters at the zero mark. Here we have a typical case of complication of attention, which is investigated on complication apparatus having a dial face with a rotating arrow. In our experiments, the subject was required to stop the arrow at the moment it passed the zero mark on the scale. He did this by pressing a button. Movement of the arrow beyond the limits of the range ± 3 scale divisions was considered an error.

While evaluating the results of tests according to the given method, the degree of subject progress in mastering the observation activity was also taken into account. The magnitude of this progress could be judged on the basis of comparing the indices characterizing the condition of attention at the beginning and at the end of the tests. This progress was evaluated depending on the decrease in the number of errors characterizing successful distribution and redirec-

tion of attention, and the increase in the absolute value of the CC, characterizing the degree of concentrating attention.

Of course, such an approach to analyzing the state of attention and its quality does not pretend to have exhaustive thoroughness, but still makes it possible to judge the general tendency of possible improvement and successful development of any particular quality of attention in the course of training, specifically, and with respect to improving attention generally.

The investigation was carried out with the participation of 31 subjects. Our subjects carried out a total of 50 programs. In order to exclude the possibility of learning the order of sequence of the stimuli and a determinable related monotony in working on the attentiometer, a certain supplementary reconstruction of the instrument was carried out and was expressed in the fact that in the process of working on the instrument the experimentor could change the order of stimuli at will.

Before the beginning of the tests, each subject was individually given instructions containing the following:

"Your problem consists in continuously observing the changing /219
position of the aircraft model, by means of moving the control lever with your right hand in a direction opposite the deviation of the model, to hold it in the normal position, upon which the light on the screen will go off. Simultaneously, you are obliged attentively to observe the instruments located in front of you, and using your left hand, to achieve a situation in which they are always in the zero position. When the lights come on, they should be turned off rapidly by pressing the appropriate button, located along the vertical below each of the lights; when the arrow of the electric pulse counter begins to rotate, you should wait until it makes a complete revolution, then try to stop it on zero by pressing the appropriate button with your left hand; upon deviation of the indicator dial arrows, it is necessary to return them rapidly and evenly to the zero position by turning the appropriate controls of the potentiometers in a direction opposite the deviation of the arrows. If you

do not return the instrument dial arrows to the zero position in a certain programmed interval of time, or if you do not succeed in extinguishing the indicator lights, the instrument will automatically reset the zero position and turn off the lights, and you will be considered to have erred. Errors will also be recorded if you make an error exceeding one division of the scale in returning the arrows of the instrument dials to zero. The basic rule for work on the attentiometer consists in attentively following the instruments on the panel, timely and accurately carrying out the necessary actions."

After clarification of the instructions to the subject, the subject was given an opportunity to become acquainted with the operation of the instrument in the process of carrying out a training series of exercises in which the program was presented at a reduced speed. After a dingle training session, the record tests were carried out; they consisted of 50 repetitions of the program and the subject worked on the instrument 5 times in each session (about 12-15 minutes). The results of the experiment were recorded in the report.

2. Analysis of the Experimental Data

Comprehensive analysis of the obtained experimental data showed that all subjects experienced serious difficulties in carrying out the observation function in the initial stage of the experiment (1-15 series of program presentation). This was objectively expressed in the fact that in the beginning of work on the instrument, they /220 were unable to maintain a stable tendency in improving concentration, distribution, and redirection of attention. In an overwhelming majority of cases, there was an improvement in one of the properties of attention, achieved at the expense of deterioration of the indices with respect to the other parameters. Thus, for example, in most subjects who strove primarily to carry out the function of observing the aircraft model, a certain degree of progress was observed in concentrating attention. The coefficient of observation increased from experiment to experiment. However, there was a simultaneous increase in the number of errors and omissions, indicating a drop in the level of distribution and redirection of attention. A similar

picture was observed in that portion of our subjects who primarily chose as their primary object the activity of distributing attention. In yielding an improvement in the indicators for distribution of attention from series to series, they did not improve the indices of attention concentration.

At the initial stage of the experiment (1-15 series), in certain subjects, this kind of tendency has a variable character. The subject could demonstrate relative success in one series in mastering an activity related to distributing attention, while in the next series or after a few series, such success was noted with respect to a different parameter. These data, although few in number, once again confirm the fact that the organization of psychological activity at the initial stages of learning does not display a stable tendency to improvement according to all the parameters of attention.

It is necessary particularly to dwell on a difficulty that appeared at the initial stage of the experiment. It consisted in the fact that the subjects immediately lowered their indices on concentration and distribution of attention, having made a serious error in redirecting attention; this naturally had an immediate negative effect on the execution of the entire activity of observation. Therefore, one can conclude that delay in redirection of attention in this case leads to a decrease in the quality of work on the attentiometer.

At this stage of the experiment, part of the subjects were characterized by stable tendencies toward improvement of the objective indices of attention distribution: the number of errors made on the lights, instrument dial arrows and electric pulse counters decreased from series to series. Certain subjects of this group who made ten errors in the training series of the experiment (out of 12 possible ones) immediately decreased the number of errors to 7-8 in the first series, notwithstanding the fact that the record series of experiments was carried out at a speed of programmed presentation significantly higher than the training one. In the subsequent period, this number of errors principally decreased. /221

Simultaneously, the index of attention concentration in the subjects of this group remained relatively stable.

It can be hypothesized that in the subjects of this group adjustment to successful distribution of attention was noted which made it possible for these subjects successfully to carry out redirection of attention as well. This is explained by the fact that the act of distribution of attention is often replaced by or usually supplemented by rapid redirection; therefore, although these are two separate qualities of attention, the boundary between them is practically undetectable during investigation. It is known that distribution and redirection of attention play a significant role in the formation of skills of sensory-motor coordination. At first, the sensory-motor action in controlling an object is made up of a chain of separate reactions, each of which has its beginning and end. Subsequently, they are combined into a flexible plastic system of sensory-motor correction of the total action being accomplished. Sensory-motor coordination in its highest forms lies at the base of occupational dexterity. Proportional to automating a skill, attention also improves and becomes post-voluntary.

And finally, at this stage of the experiment a very small group of subjects was isolated in which the objective indices — concentration, distribution, and redirection of attention — progressed from series to series. In the course of the experiment, slight fluctuations in the parameters of attention were observed in individual subjects, but all the same, the general picture of their changes indicated that here there was a good and clearly defined tendency toward stable formation of sensory motor coordination. Therefore, even here the improvement of attention occured in continuous relationship with the formation of sensory motor skills and abilities.

In our investigation there was clear interest of the subjects in successfully accomplishing the assigned problems. In most of them, with rare exceptions, increased interest in the results of the test was noted. This was interest enriched with a sense of novelty, interest due to the attractiveness of the activity. After

completing the experiment, many of our subjects came to us at their own initiative in their free time with a request to subject them to repeated investigation in order to improve their results. Here the clearly voluntary attention was already determined by interest in the final goal of the activity and interest not in the process of /222 the activity itself, but in its result, a cognizant interest related to human striving. Voluntary attention was maintained through the intermediary of interest, at the basis of which most voluntary attention subsequently appears. In human labor activity, strong interest in the result usually transfers to interest in the process itself.

The effect of qualities of personal will for successful accomplishment of actions in observation also appeared in our experiment. In the process of working on the attentiometer, we frequently observed this picture; a subject in seeing that he is not successfully coping with the work, altered his external appearance (took on a concentrating posture, but his lips to the point of pain, and verbally declared that in the next series he would produce a better result) and actually improved his indices from series to series. At the same time, there are also subjects who became confused in the course of the experiment and therefore produced bad results. Each error recorded by them entailed another following it.

Hence, comprehensive analysis and summarization of the data obtained by us at the initial stage of the experiment (the first 15 series), made it possible for us to establish the presence of significant individual differences in concentration, distribution, and redirection of attention and to note several groups of subjects who were distinguished according to some of the parameters, in connection with this. Additionally, in the course of further studying the given question, the general picture of dynamics of these parameters significantly changed, which in the final analysis led to a decrease in the number of planned groups and the isolation of a number of general principles of the formation of attentiveness as an important occupational quality of the operator.

With this goal, in addition to the analytical approach, we

estimated the results of each property of attention using the integral approach and directed our efforts to seeking a general criterion characterizing the state of operator attention.

In our investigation, this criterion is determined by the general state of attentiveness (S_a), according to the following formula:

$$S_a = \frac{1}{2}\left[\frac{70-(n_r+n_{re})}{70}+C_{ob}\right] \qquad (A)$$

where S_a -state or general level of attention; 70-maximum number of possible errors in distribution and redistribution over 5 programs; n_r -number of errors in distributing attention; n_{re} -number of errors in redirecting attention; C_{ob} -coefficient of observation. /223

We shall first dwell on the data characterizing the general state of the subjects' attention. 31 people who participated in the experiment produced an increase in the value of S_a that ranged from 0.01 to 0.30. In 24 of them, in the learning process, this progress occurred with respect to all of the properties of attention studied in the experiment. In the remaining 7 subjects, a decrease in the indices was observed with respect to individual parameters. Such a decrease occurred in 4 subjects with respect to distribution of attention, and three subjects with respect to redirection of attention. Of the indicated three subjects, besides regression with respect to redirection of attention, in one subject the result on concentration of attention also decreased. But this fact did not affect the general tendency of development of attention on the whole: these 7 subjects still generally produced a positive increment within limits ranging from +0.20 to +0.01. Hence, we can state with complete confidence that in the process of our experiment the general state of attention in our subjects increased, although to different degrees.

Data indicating improvement in the concentration of attention proved to be characteristic. 30 of the 31 subjects showed progress in improving this quality. This progress was achieved by our subjects within limits of an increase in C_{ob} from +0.01 to +0.41. In all probability, this fact is explained in that the activity related

to controlling the aircraft model was the primary task in the experiment. The effect of this factor is also confirmed by the fact that significant progress was achieved by our subjects in the area of distribution and redirection of attention.

In the process of learning to work on the attentiometer, one can clearly define two stages in the development of the state of attention.

At the first stage, general attentiveness is still not adequately expressed. The actions of the subjects and the character of errors made by them have a "chaotic" character, and the deterioration of data with respect to one of the indices immediately has an effect on the others. Errors made in redirecting attention entail the appearance of erroneous actions with respect to the concentration and distribution of attention. Basically, the subjects strove to produce better results with respect to one or two parameters. In the process of the first three series of experiments, the subjects made a large number of errors in redirecting attention (of the 10 possible errors over 5 program presentations, they acted in error from 5 to 7 times). /224

At the second stage of activity in carrying out observation, activity acquires a growing coordinated, orderly, integral and automatized character. Progress is noted in the indices with respect to all parameters of the investigated properties of attention. The errors made do not have a significant effect on the other indices. A tendency toward improving all of the investigated properties of attention begins to emerge and errors in redirecting and distributing attention gradually decrease. A new function primarily emerges — self-control of actions by the operator.

The two phases in the development of attentiveness indicated here agree very well with the general principles of human working capacity. Many investigations show that working capacity is not a stable characteristic. It changes in the process of work according to certain phases. In the final analysis, its dynamics are determined by the dynamics of changes in the reflex activity of the human nervous

system.

The first phase is characterized by increasing working capacity — "the accumulation of working potentials". Here there is a functional restructuring and establishment of the dynamic stereotype. The initial period of work is characterized by the known "initial disagreement" between the new demands made on the man and the existing state of his functions. With all other conditions being equal, the value of this "disagreement" determines the duration of adjustment to work (the period of "breaking-in"). The speed and occasionally the accuracy of human actions are low in the first phase.

The second phase of relatively stable working capacity is the period when the establishment of the stereotype is complete and the activity of the organism acquires a harmonic unity and integrity provided by the stereotype, without significant loss in the speed and accuracy of accomplishing actions. This phase is characterized by automatization of the rhythms and tempos of activity of the separate regions of the nervous system.

One of the most important manifestations of the change in coordination of psychological processes and functions in the course of activity is the change in properties of attention that characterizes the level of adjustment of the organism's systems that accomplish reception and restructuring of information. In the first phase of working capacity (breaking-in), distractions of attention are frequent. In order to concentrate, the subject must exert the force of will. For the phase of high and relatively stable working capacity, post-voluntary attention is characteristic. Here the frequency of distractions significantly diminishes and, additionally, concentration does not require special effort. This fact also became clear in our experiment at its conclusive stage of increasing the general level of attentiveness. /225

Moreover, it is difficult to achieve complete stability of attention over the course of a long period of time even at the second stage of working capacity. More or less frequent distractions are

unavoidable. One of the reasons for their appearance is sharp changes in the environmental situation and the inner world of the subject himself, and foreseeing the effect of these factors even under the conditions of an ideally designed experiment is not always successful.

But the essence of the matter does not only consist in external stimuli. It is known that certain spontaneous fluctuations or so-called 'fluctuation' are inherent to attention; this is due to the dynamics of the neuroprocesses, and is probably also related to the intero- and proprioceptive impulses. Recent investigations in this field have established that fluctuation is not subordinant to a certain rhythm, as was thought earlier concerning this subject, but an an arhythmic character. The character of the spontaneous fluctuations (duration of concentration, number and duration of distraction) differs in different people.

Although psychology has certain data on the dynamics of fluctuations in attention at different phases of work, this question has still not been studied in adequate detail. There is no complete clarity relative to the causes of fluctuations, and the relationship of their frequency and duration with the character of activity being carried out, itc., are unkown. Nevertheless, a knowledge of the dynamics of fluctuation has great significance for solving the problem of operator reliability, since it is known that interruptions in his work are frequently due to fluctuation of attention.

We shall now examine in greater detail the experimental data that characterize the increase in concentration of attention in the process of working on the attentiometer. The absolute value of progress in the degree of concentration of attention was within limits of from 0.01 to 0.41, and relatively low progress, (0.01 to 0.9) was shown by 12 of 31 subjects. The dynamics of transition from series to series and from one session to another were accompanied by an unswerving increase in the coefficient of observation. Hence, the conceptual link uniting the varied dynamic content into a more or less structured system concentrated around a single center relating /226
to a single activity comprizes the basic prerequisite of stable

attention.

Additionally, we have reason to assert that the concentration of attention and its stability are dependent upon the individual characteristics of the higher nervous activity of the subjects. Here, the capacity for long-term maintenance of one's attention at a certain level by means of force of will is primarily required, even in a case when the content of the attention is not of direct interest and its maintenance in the center of attention is linked with certain difficulties.

The many investigations of L.B. Yermolayeva-Tomina, who concerned herself with the problem of individual differences in the concentration of attention and strength of the nervous system, convincingly demonstrated that concentration of attention is directly dependent on the strength of the basic neural processes. This concept is also indirectly confirmed by the studies of U. Siyman, S.A. Paŭzhayte, A. Turovskaya, A.R. Luriy, D. Vuldridzh and other psychologists not particularly concerned with problems of individual differences of attention, but in the process of whose experimental investigations confirmation was obtained of such a direct relationship between the concentration of attention and the strength of the neural processes of stimulation and inhibition.

One can hypothesize that the level of concentration of attention depends on the strength and uniformity of the basic neural processes, while at the same time a basic role in redirection and distribution of attention is probably played by their lability. We say "probably" because up to now no experimental investigations that would confirm this hypothesis have been conducted, and in the available psychological and physiological literature this hypotheses is only expressed applicable to the theoretical aspect.

The experimental data obtained by us indicate the presence of certain relationships among the improvement of concentration and the distribution and redirection of attention.

At the initial stage of the experiment, the coefficient of observation in an overwhelming majority of our subjects fluctuated from 0.13 to 0.50 and remained approximately the same up to a sharp improvement in the indices with respect to distribution and redirection of attention. As soon as automization of the sensory-motor activity related to the distribution and redirection of attention began there was an unswerving increase in the coefficient of observation, i.e., /227 the degree of concentration of attention increased at a noticeable tempo. This growth increased from series to series by a slight value and by the end of the experiment already comprized more than 0.75. Thus, in 28 subjects value C_c at the end of experimental learning reached 0.70 - 0.85 and comparatively low indices of the coefficient of observation (on the average 0.53) were observed in only 3 subjects.

We shall examine similar data that characterize distribution of attention.

The absolute value in the progress of this quality of attention varied from +3.4 to -2.0. Four of our subjects showed negative values of the progress of this quality, two subjects yielded no increment, but the remaining 25 showed an absolute increment ranging from 0.1 to 3.4. Consequently, the general tendency toward improvement that was recorded by us with respect to the attention concentration parameter was not shown here. We shall examine the possible causes of this seeming lack of correspondence. The fact of the matter is that the above mentioned 6 subjects who did not yield a positive increment with respect to this parameter concentrated all of their attention in the initial stage of the experiment in maintaining the aircraft model in the neutral position and attained good indices in this respect. When it actually became possible for them to improve their indices with respect to the other parameter — distribution of attention — the mechanism of sensory-motor coordination was still not adequately automatized in them, which had a negative effect on the distribution of attention. Hence, in this case the improvement in concentration of attention left its negative imprint on the accomplishment of the entire activity as a whole.

Here, we can speak to a known degree of the fact that in these subjects there was still a low volume of attention, besides the inadequate distribution of attention, since these two qualities are intimately interrelated. Consequently, one can also mention the limited nature of the field of attention. As a rule, in these subjects there were more modest indices with respect to improvement and the other qualities of attention.

Additionally, a significant portion (41.9%) of our subjects achieved good indices with respect to the distribution of attention. This is indicated by facts of a decrease in errors at the conclusive stage of the experiment. Thus, in the 9th series of exercises, the mean number of errors made by the subjects decreased on the average from 8-9 to 0.8 - 3.6. The successfulness of distributing attention in an overwhelming majority of subjects could be explained by their /228 rapid formation of the sensory-motor skill which made it possible successfully to distribute their attention to other actions.

All of the above makes it possible to assert that the improvement in distribution of attention is directly related to and depends on the speed of developing and automatizing the sensory-motor pathways.

In conclusion, an analysis should be made of the data pertinent to a characterization of redirecting attention. The absolute value of progress of this property varied from 0.6 to 0.1. If at the initial stage of learning a significant decrease in the number of errors was observed in only four subjects, then at the concluding stage their number grew to 11 subjects. These data indicate that the redirection capacity of attention under conditions of appropriate learning can not only successfully be improved, but can also accompany the development of the capacity rapidly to orient one's self in the situation and take into account the changing significance of its different components.

In the course of the experimental investigations significant individual differences in the development of the subjects' attention were detected. One can hypothesize that individual characteristics of temperment lie at the base of these differences; these individual

characteristics determine the strength, lability, and uniformity of the basic neural processes.

An unquestionable service in the development of this problem is the study of B.M. Teplov, V.D. Nebylitsin and their associates. Thus, an important contribution to studying the problem of attention with respect to studying the strength of the neural processes was made by L.B. Yermolayeva-Tomina [9], who clarified the nature of the interrelationship of concentration of attention and the strength of the basic neural processes. Her experimental investigations showed that in persons with a weak nervous system the dominant focus is easily inhibited by secondary sonic stimuli; in persons with a strong nervous system an adequately strong dominant focus is created in the optic analyzer that attracts stimulation from the other analyzer systems to itself.

The relationship of the other characteristics of attention and the uniformity and lability of neural processes was studied by A.A. /229
Makogonova [10]. She established the relationship of distribution of attention and lability and uniformity of the basic neural processes.

B.N. Birman [11] indicated three criteria of the strength of the stimulation process, among them, in second place after the "degree of working capacity" is "the volume of complex reactiveness", which means certain characteristics of the concentration of attention. S.N. Davidenkov [12] emphasized that one of the very fine criteria of weakness of the neural processes is an intensive striving of the personality to avoid intense, active attention. N.G. Popesku-Nevyanu writes that in the weak type attention is distinguished by its low volume, easy fatigue, relatively weak concentration, difficulty in distribution and a weak capacity for redirection.

The information cited above and based on experimental investigations provides a basis to hypothesize the presence of a relationship of the concentration of attention and the strength of basic neural processes. With respect to the distribution and redirection of attention, we only advance the hypotheses of the relationship of

the properties of attention with lability and uniformity of the basic neural processes. The given hypothesis requires experimental confirmation.

Conclusions

1. The complex attentiometric investigation of the distribution, redirection, and concentration of attention during the work of the operator in the regime of observation conducted by us made it possible to establish a number of characteristics of the development of these properties of attention in the learning process.

2. Analysis and summarization of the data obtained in the experiment made it possible to note two stages in the development of attention. In the first stage, general attentiveness is still not adequately expressed. The actions of the subjects and the character of errors made by them have a "chaotic" character; deterioration of indices with respect to one of the indicators immediately affects the others: errors made in redirecting attention entail the appearance of erroneous actions pertinent to concentration and the distribution of attention; basically the subjects strove to demonstrate good results on one or two parameters. In the process of the first series of experiments, the subjects made more errors in redirecting attention. /230
In the second stage, activity on accomplishing observation acquires more and more coordination, orderliness, integration and automation. Progress of the indices with respect to all parameters of the investigated properties of attention is noted; making errors does not have a significant effect on the other indices; a tendency to improvement of all the investigated properties of attention begins to merge; errors in redirecting and distributing attention gradually decrease. A new function primarily emerges — operator self-control of actions.

3. A comparative study of the indices characterizing the development of separate properties of attention has made it possible to establish the presence of a certain relationship among the improvement of concentration, distribution and redirection of attention. Thus, in an overwhelming majority of subjects (90.3%), the degree of con-

centration of attention began to increase proportional to the improvement in distribution and redirection of attention. Together with this, part of the subjects (20%) demonstrated a negative effect on the distribution of attention resulting from extreme concentration of attention. At the end of experimental learning in these people, in addition to high indices of concentrating attention, there was a significant decrease in the parameters characterizing the distribution of attention. Significant progress in the development of this property of attention was observed in 41.9% of our subjects. A direct relationship was also found between the distribution of attention and automation of sensory-motor acts. The development and automation of skills enable an increase in the indices of attention distribution.

4. Development of the property of being able to redirect attention by the aid of exercises proved least effective. Thus, in the process of learning 33% of our subjects were not observed to have significant changes in his development. At the same time, in 10% of the subjects at the end of experimental learning there was a deterioration in the indices of attention distribution. It can be hypothesized that the difficulties of redirecting attention are a manifestation of the individual — characterological characteristics of the subjects.

5. Consideration of the general and individual characteristics of the development of attention revealed in this investigation opens pathways for occupational selection and making an individual approach to students during their mastery of the operator's profession.

REFERENCES

1. Mileryan, Ye.A. Voprosy teorii vnimaniya v svete ucheniya I. P. Pavlova o vysshey nervenoy deyatel'nosti. (Questions of the Theory of Attention in the Light of the Teachings of I. P. Pavlova Concerning the Higher Nervous Activity.) Author's abstract of a Candidate's Dissertation, Kiev, 1954, p. 12.

2. Pavlov, I.P. Poln. sobr. soch. (Complete collected readings), Vol. 3, book 1, Moscow, 1951, p. 34.

3. Ukhtomskiy, A.A. Soch. (Readings), Vol. 1, Leningrad, 1950, p. 282.

4. Ukhtomskiy, A.A. Ibid, p. 207.

5. Pavlov, I.P. Poln. sobr. soch. (Complete Collected Readings), Vol. 4, Moscow, 1951, p. 428.

6. Gurvich, T.Kh. An Objective Evaluation of the Operator's Work during Continuous Control of Several Parameters. In the collection: Tezisy dokladov na II s'yezde Obshchestva psikhologov (Abstracts of Reports Given at the II Congress of the Society of Psychologists), No. 3, Izdatel'stvo APN RSFSR, 1963, p. 66.

7. Yoseliani, N.K. and A.L. Narinskaya. The Development of an Experimental-Psychological Method for Studying the Stability and Redistribution of Attention under Conditions of an Assigned Topic of Continuous Intellectual Activity. In the collection: Tezisy dokladov na II s'yezde Obshchestva psikhologov (Abstracts of Reports Given at the II Congress of the Society of Psychologists), No. 3, Izdatel'stvo APN RSFSR, p. 52.

8. Mileryan, Ye.A. and O.P. Shvetsov. A General Structure of Operator Activity and Certain Conditions of its Formation. "Voprosy psikhologii", 1966, p. 4.

9. Yermolayeva-Tomina, L.B. Proyavleniye sily nervnoy sistemy v kontsentriro vannosti vnimaniya. (The Strength of the Nervous System in the Capacity to Concentrate Attention.) Author's abstract of a Candidate's Dissertation, Moscow, 1960.

10. Makogonova, A.A. The Distribution of Attention among Radio Operators with Respect to Typological Differences in the Higher Nervous Activity. Materialy soveshchaniya po psikhologii. (Materials of a Meeting on Psychology), Moscow, Izdatel'stvo APN RSRSR, 1957.

11. Birman, B.N. Experimental Sleep. Materialy k voprosu o nervnom mekhanizme sna. (Materials on the Problem of the Neural Mechanism of Sleep.) Leningrad, "Gosizdat," 1925.

12. Davidenkov, S.N. Evolyutsionno-geneticheskiye problemy v nevropatologii. (Emotional-Genetic Problems in Neuropathology) Leningrad, 1947.

N75 17955

VERBALIZATION AND IMAGERY IN THE PROCESS OF FORMATION OF OPERATOR LABOR SKILLS

V.V. Mistyuk*

Occupational labor training, in the process of which students master a certain system of knowledge, capacities and skills in preparing for their independent work, is carried out with obligatory participation of verbalization and image. In human labor activity, these components are an inseparable whole. /231

In a number of psychological investigations in the psychology of training (L.V. Zankov, G.S. Kostyuk, N.A. Menchinskaya, V.V. Chebysheva and others), it has been established that the relationship of verbalization and image (clarity) changes in all types of training activity depending on the content and form of the material being mastered.

In the cited investigations, the subject is primarily verbal explanation and image demonstration used by the instructor, and significantly less attention is paid to verbalization and image used by the students themselves in mastering a certain system of knowledge, capacities and skills in the process of training-labor activity.

In investigations in engineering psychology, questions of using verbalization and image as means of presenting information necessary to the operator in his activity have been given an adequate place. [1]

Besides obtaining the required information in the process of operator work, an active comparison of the sensory image and concepts concerning the image with the results of his activity constantly goes on. Thence arises the question concerning the nature and specific

*Kiev, Institute of Psychology of the UkSSR

characteristic of the formation of the image-standard. This question /232 has been studied in detail in the works of B.A. Oshanin, L.R. Shcherbak, and E.N. Konrad [2]. One of the problems B.A. Oshanin investigated was establishing the characteristics of formation of the operational image in the process of isolating the information content of signals.[3]

Our investigation was directed toward clarifying the role of verbalization and image on the part of the operator himslef in the course of his mastery of the sensory-motor skills of control.

Based on the data of investigations we conducted earlier, we hypothesized that one of the conditions of increasing the effectiveness of the process of mastering sensory-motor control skills is the presence of the created program image. Goal-directed, independent determination of this image carried out on the basis of processing incoming information is linked with utilization of internal and external speech and activates the psychological activity of the operator, accelerating the process of mastering the required operations and increasing its effectiveness.

With the goal of verifying this hypothesis, in an experiment we traced the process of development of images in subjects and determined the effect of this earlier-formed image on the course and effectiveness of formation of the sensory-motor control skills. In the process, the possibility of transfering earlier developed qualities of movements (speed, accuracy, and coordination) to the new conditions of operator activity was also clarified.

The investigation was conducted by the method of a laboratory simulation experiment using a special device for studying operator activity; the device was designed by Ye.A. Milerian *.

The device has a subject control panel and an experimentor control panel. The subject control panel consists of a vertical information panel and a slanting control panel. The right hand portion of the information panel has a semitransparent screen with a coordi-

*A description of this device is given on page 19 of this book.

nate grid applied to it. On this screen the subject sees a point moving along a curvolinear trajectory. Next to the screen are images of 6 curvolinear lines, each of which is a possible trajectory of the white point. Beneath each of the standard lines is a switch which is used for objectively recording the time spent on recognizing /233 the shape of the trajectory of the white point. The subject also sees a red point on the information screen whose movement he can remotely control by means of using a lever mounted on the slanting panel. By manipulating these levers, the subject can move the red point on the plane of the screen.

The subject control panel has two rows of buttons bearing numbers 1, 2, 3 ... 10. Above the upper row of buttons is written "vertical", and above the lower row — "horizontal". These buttons are used for subject transmission of the coordinates of the white point. The apparatus automatically fixes the number of correct and incorrect actions made by the subject in transmitting the coordinates.

The control panel of the experimentor contains six counters, a switch for turning on the circuit, a program switch, a starting button and stopping button for the program, a master switch and other instruments.

The pulse counters of the experimentor control panel record the following parameters of subject work:

1. Time of accomplishing the program.
2. Time of observation, over which the subject coordinates movement of the point controlled by him with the trajectory of the white point.
3. The total number of coordinate calculations transmitted by the subject over the course of the experiment.
4. The number of correct coordinate calculations.
5. Time spent by the subject on adequate identification of the shape of trajectory of the white point.

Twenty subjects participated in our experiments. Each of the subjects had to identify the image of trajectory in the process of observing the moving white point, periodically transmit its coordinates and, by controlling the red point, master the sensory-motor skill of control (the subjects were divided into control and experimental groups of ten people each).

During the experiment, the subjects mastered the skill of controlling levers, moving the red point along the trajectory of the white point by their aid. The experimental group of subjects had to determine this trajectory independently, while it was given to the control group in ready form. In the first series of experiments conducted in the experimental group, formation of the control skill in the subjects occurred in the absence of a ready program image. The subjects had independently to identify this image in the process of observing the evolutions of the white point. /234

In following the movement of the white point along the screen, the subjects had to fix its coordinates by pressing the appropriate buttons when the point stopped at the command of the experimentor. The recording counters recorded the time, reaction speed, and errors made in transmitting the information (correct or erroneous button pressing).

In this part of the experiment, we also had to trace how the process of formation of the visual program image was being formed. With this goal, it was also suggested to the subject that besides transmitting information on the coordinates of the white luminescent point by pressing the button when it stopped, he also note these coordinates on paper containing a grid identical to the coordinate grid of the screen. After carrying out each assignment in tracing the path of the moving luminescent point, the subjects attempted to re-create the trajectory of its movement in a drawing. During this process they used light pencils which made it possible to calculate the results of accomplishing each task separately.

The solution of this type of problem was repeated until the

image-trajectory of the white point was identified from among the series of six other standards, after which the subjects proceeded to the second series of exercises directed toward sensory-motor mastery of the control skill. In the process of carrying out the exercises, the skill of lever operation was formed in the subjects. By manipulating the levers, the subjects could move the red luminescent point along the trajectory of the white point. Work under these conditions enabled formation of capacities to trace movement of an object, to conceptualize the trajectory, and to act in accordance with the obtained information.

The process of formation of the skill of lever control was reflected in the results of the experiments, where the following were fixed: the number of errors made by the subjects; time used by each subject in accomplishing the assignment; time of tracking, i.e., of moving correctly according to the program line; number of exercises required by each subject for complete mastery of the skill (rapid and error-free accomplishment of the assignment).

In the second series of the experiment (the control group), formation of the simulated skill of the operator was carried out according to an assigned program that was visually perceived by the subjects in the form of a luminescent line. Therefore, it was unnecessary to develop the corresponding program image in its independent determination, as we had required of the experimental group. /235

This assignment was given subjects of the control group: by operating the levers, correctly and accurately to move the red luminescent point along the assigned line.

In both variations of the experiment, the quality of activity of our subjects as control panel operators was periodically checked. At the command of the experimentor, they transmitted information on the coordinates of the point at the moment it stopped by means of pressing the buttons.

The experiment began with the accomplishment of preparatory

assignments whose goal was to familiarize the subjects with the operation of the experimental device, to exercise in tracking the path of the moving luminescent point along the screen, and to fix the coordinates of its periodic stops by pressing the special buttons.

The assignments given the subjects were easily carried out by them and were carried through to completion. Also easily mastered was learning which buttons should be pressed (the upper row — position of the luminescent point on the horizontal, lower row — its position on the vertical).

The subjects were greatly attracted by the use of terms new to them, such as "transmit coordinates", "operator", "control panel," etc. In talking with the experimentor or in conversations among themselves, they used these words that were attractive for them with delight.

Fixing the coordinates of the stopping point of the luminescent point on the experimental device emerged as simulation of operator activity (reception of corresponding information, its processing, and transmission), which the subjects liked very much and which increased their interest in accomplishing the assignment. They expressed the thought that when they went to work as operators all these exercises would be very useful.

All of the above convinced us that preparatory assignments, including the requirement to track the path of movement of a luminescent point along the coordinates of the screen and to fix the coordinates of the stop of this point by means of pressing buttons were, fully realized by the subjects and carried through to completion. Their execution, however, proved to be more complex. This is the reason: the white luminescent point moved along the screen over a trajectory invisible to the subject. The stops of the luminescent point, during which it was necessary to fix its coordinates, lasted /236
no more than three seconds. After three seconds, movement continued and the subjects were unable to permit the point to leave their

field of vision, for in that case the danger of delaying in fixing the coordinates at its next stop would have arisen. And it was too difficult for them simultaneously to operate the buttons and trace the movement of the luminescent spot, since they had not succeeded in automatizing either of these operations, or in coordinating them. It is in fact known that such coordination is one of the signs of adequate formation of the appropriate skills.

This is why the results of carrying out the preparatory assignment, as should have been expected, proved low. Thus, of 30 possible button pressing operations by 10 of the subjects, only 5 were correct. And those, at the admission of the subjects themselves, were dubious, random results, since the subjects themselves sensed that they were confused and didn't know where to look first, at the screen or at the buttons. And the subjects still proved to be unprepared for coordinated actions.

The data obtained during the accomplishment of this preparatory assignment showed that it was difficult for the subjects to distribute their attention: simultaneously to press the buttons while observing the screen. The applied speed, accuracy, and coordination of working movements of their hands were insufficient. And it is just these qualities that provide what is known as general capability.

In accomplishing the preparatory assignment again, certain subjects attempted to help themselves by verbalization and speech at their own initiative. They named and aurally pronounced the coordinates of the luminescent point as soon as it had stopped, and pronounced the coordinates while pressing the buttons.

Including speech in their activity clearly produced results. Verbalization aided in directing attention to perceiving the coordinates and to selecting the necessary buttons. If when carrying out the assignment the first time they each made three possible errors, then the second time with the participation of verbalization, they made only one each. Subsequently, the coordinates of the luminescent point were transmitted correctly by them. True, these were people

interested in equipment and who had mastered quite developed motor skills (general capacity).

Subjects Zh., P. and T.L. attempted to aid themselves by other methods. As soon as the moving points stopped, they moved their fingers to the place where it had stopped and then attempted to press the buttons as rapidly as possible. However, this additional action took up time and did not accelerate accomplishment of the assignment. They soon refrained from this "method" and also began to pronounce the coordinates of the stopping point, which helped /237 them more. The four remaining subjects did not use any visual methods to aid themselves in accomplishing the assignments.

Hence, the results of accomplishing the preparatory assignments indicated significant difficulties in mastering the control skill that arose as the result of the subjects' incapacity to distribute their attention in a timely fashion and with adequate speed, accuracy, and coordination to accomplish the working movements.

The first basic assignment for the experimental group consisted of the subjects themselves determining the trajectory of the white luminescent point along the screen, the trajectory, which would become the program image of their actions in the second part of the experiment, and according to which they would have to work, mastering the skill of lever operation.

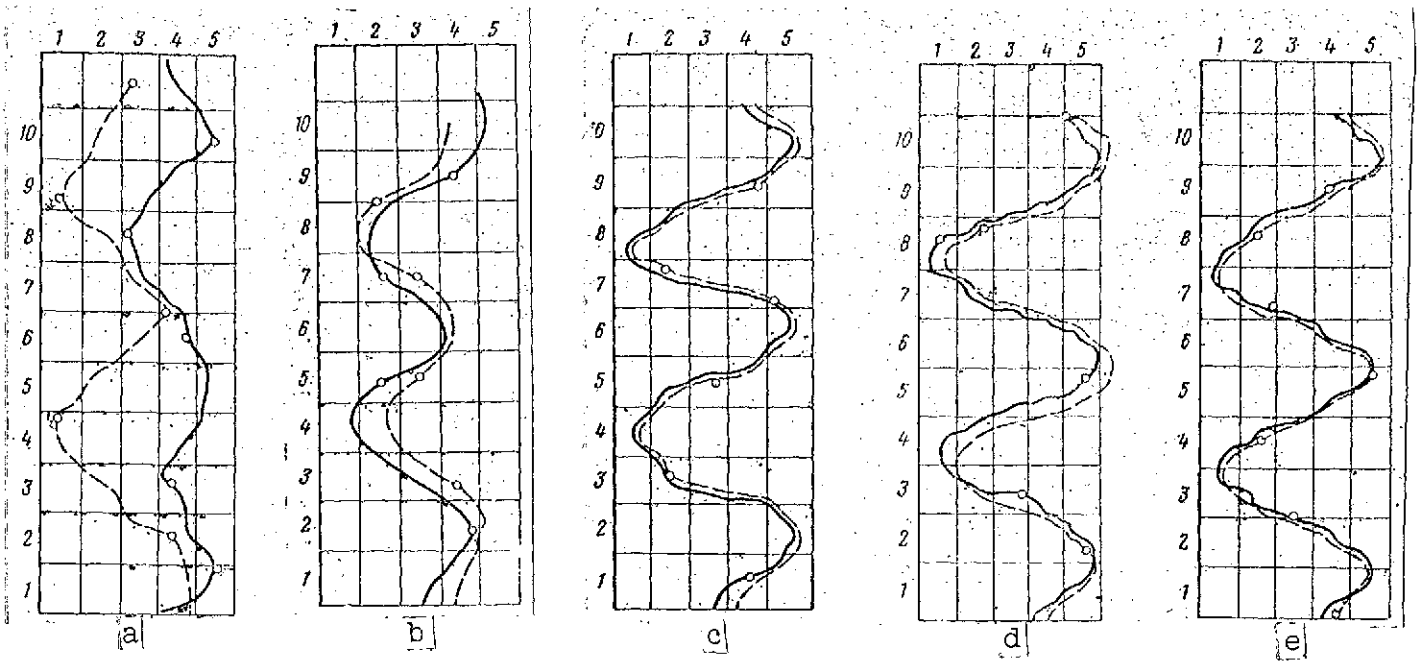
It was necessary to accomplish this assignment, first, on the basis of information obtained as the result of observing the movement of the indicated object and of remembering the image of the trajectory followed by it; second, on the basis of information concerning the coordinates of the stops of this object in certain places of the screen. This information was fixed (as in the preparatory assignment) by the subjects themselves by means of pressing the appropriate buttons, and the coordinates were also marked in pencil on grid paper. Following the completion of each exercise, the subjects attempted to duplicate the trajectory of the white point in a drawing.

Naturally, from exercise to exercise duplication became more and more adequate, which we could assure ourselves of, since during each succeeding exercise the coordinates of the stopped point were also fixed on the screen and its trajectory was duplicated on the screen by the experimentor, using a colored pencil. The first exercise — red pencil, the second— green pencil, the third — yellow pencil, etc.

Comparative analysis of the drawings obtained during all exercises of the experimental assignment made it possible to trace the various stages of development of the trajectory image of point movement in the plane of the screen and to establish the presence of characteristics of perceiving and processing information by the subjects of the experimental group. Thus, below are the drawings of Yura G. and Dima B. Both the subjects are very conscientous and /238
thoughtful. They are subjects who discussed and planned their actions aurally during the accomplishment of the preparatory assignment. Of course, both of them made errors, but while Dima corrected them without excessive agitation, Yura had a severe reaction to each failure. In striving to justify himself, he blamed the experimental device on the whole for being imperfect, and ascribed error in transmitting indices to the counters. It was necessary several times to demonstrate the operation of these counters with the participation of his comrades in order to convince him that the errors were the fault of Yura himself. This disturbed and angered him.

Thus, in the first basic experimental assignment, the subjects were asked independently to determine the trajectory of the white point along the screen and to duplicate it in a drawing (the program of their future actions). As Figure a shows (the result of accomplishing the first exercise), both subjects simply joined the lines of the coordinates of the point stop as they seemed to them. This was also the case in the drawings of the other 8 subjects. None of them kept an image of the trajectory of the point along the screen in their attention, although they obligatorially followed it. The negative evaluation of the first image, given by the experimentor (even without explanation) forced the subjects to think and more

Figure 1.



attentively relate to what they had perceived on the screen.

As the result of a repeat accomplishment of the exercise (Figure b), certain changes were already noted. The trajectory depicted by the subjects approximated that along which the point had moved. Apparently, they had used the data of their memory to a certain extent, the image that developed during their following the movement of the luminescent point along the screen grid. The data of Figure c /239 and the subsequent ones (Figures d and e) proved to be still more adequate. In these, one can already see the attempt not only to determine, but also to depict the trajectory of the luminescent object in the general form.

The sequencial imagery of the trajectory followed by the point obtained by us and accomplished by all our subjects confirmed the idea that the creation of any image in the human consciousness is not a one-time image or photography of the object. It is always a process that is enriched in the course of human activity and its results, including more and more signs, becoming an integral and complete image of reality. S.L. Rubinshteyn wrote the following on this subject: "...the image of objective reality is itself a process of subject activity, in the course of which the subject image

becomes more and more adequate to its object." [4]

During the accomplishment of the assignments, at first all the /240
subjects considered only the information from the coordinates of the stopping point of the moving object which they had fixed. No one paid attention to the sensory impressions obtained from following its movement. Obviously, the points drawn on the grid paper emerged as the result of the voluntary activity of the subjects, on which their attention had been concentrated. Perception of the trajectory of the point along the screen and tracking its path were of an involuntary character and did not become the object of the psychological activity. Therefore, the appropriate image also did not appear. Sensory impressions become an image if the objects evoking them emerge as objects of identification, and if these objects enter the range of human activity. Therefore, the first drawings of all subjects of the experimental group were not images of the trajectory of the moving, observed object, but only a connection of the coordinates drawn by the subjects themselves on the grid paper.

However, as soon as it became necessary for the subject to be more attentive in order adequately to transmit the trajectory of the luminescent point, tracking this movement acquired new significance. They began to direct their attention not only at the stopping coordinates of the moving object, which was necessary to fix the coordinates, but also to its trajectory along the screen grid. The object of their reflected activity was also movement, as the result of which the required program image appeared in their consciousness. Figures 4 and 5 are a confirmation of this.

After the subjects had determined the program, they were asked to choose the one adequately depicted by them from the six sample programs, after which they proceeded to accomplish the assignments in which formation of the sensory-motor control skills occurred.

The goal of this part of the experiment was to clarify the conditions enabling formation of operator skills.

We attempted experimentally to demonstrate the significance of the program image of accomplishing labor actions earlier determined by the students themselves, as well as the students own verbal discussions and planning for successful formation of labor operating skills. In the psychological literature, this question has been inadequately discussed.

Both groups — the experimental and the control — participated /241 in the experiment. As has already been shown, the subjects of the experimental group carried out an assignment according to the program determined by them in the first part of the experiment. The assignment consisted in moving the red liminescent point according to the program shown on the screen in the form of a luminescent line by operating two levers. Movement of the red point by the aid of the levers simulated operation of the controlled object.

The same assignment, but one carried out according to a program assigned by the experimentor was given to subjects of the control group. The participants in this group accomplished preparatory assignments in tracking the movement of the luminescent point and in fixing the coordinates of its stops. However, the shape of the trajectory of this point was not determined.

By working in parallel with two groups of subjects, it was possible for us to compare the obtained data and to find an answer to the question of interest to us: under what conditions are operator skills more successfully formed: the role of image and verbalization in this as they are employed by the students themselves.

In compiling the graph given in Figure 2, it is easy to see that from the first experimental exercises the average results of accomplishing the assignments by the subjects of the experimental and control groups greatly differ from each other.

Thus, subjects of the experimental group correctly moved the red point along the luminescent line 47% of the time used to accomplish the assignment in the first exercise, while at the same time

the control group correctly worked only 16% of the time in accomplishing the first exercise. This occurred in spite of the identical number of preparatory exercises in tracking and fixing the stopping coordinates of the luminescent point in both groups.

Further exercises, as is shown by the lines in Figure 2, the result of a gradual increase in the percentage of time during which correct tracking and movement of the red luminescent point along the trajectory of the white point occurred. Over the first five exercises, the percentage increment with respect to correct accomplishment of the assignment by both groups moved evenly and in parallel. This continued in subjects of the control group in the subsequent exercises as well. Beginning with the sixth exercise in subjects of the experimental group, there was a sharp increase in the percentage of time of correct tracking and movement of the object. The data cited by us confirm the hypothesis that the presence of an /242
earlier formed programmed image of their future actions in subjects positively affects the formation of the corresponding skill.

Psychologically this can be explained by the fact that in the presence of such an image the subjects can foresee where, and how and by what coordinated hand movements in operating the levers one should move the red luminescent point in order that it not deviate from the program, i.e., from tracking, the subjects changeover to anticipation on the basis of the anticipated image. The same subjects who earlier did not have a formed image could not anticipate the perception of information concerning movement of the point. The subjects had to obtain this information and process it, and only then react with appropriate movements of both hands, based on the information. Transition to anticipatory imagery made it possible to foresee their future actions without waiting to obtain information, which accelerates accomplishment of the assignment and leaves more time for identification of the required system of working movements. All of this accelerates the process of skill formation and strengthening of a certain system of movements, at whose basis lies the corresponding dynamic stereotype.

The presence of a program image of future actions in the consciousness of the subjects enabled them to transfer from tracking to anticipating the track during the accomplishment of the assignments, which created favorable conditions for activity that was higher with respect to tempo and results. The gradual transition from tracking to anticipation is one of the conditions of automatizing any labor operation. /243

The positive significance of the anticipatory image in occupational training has also been noted in the investigation of Ye.A. Mileryan. In studying the psychological characteristics of formation of operational-control skills on a device of his own design, Mileryan paid attention to the role of the image in this activity as well. The investigator points out that after acquiring the capacity to identify the image of the trajectory of the luminescent point, a restructuring of the actions of the subject-operator occurs. The subject begins to foresee the course of events: "transition to anticipating the course of actions as a strategy creates favorable conditions for accomplishing the functions of regulation and control of the processes being controlled ..." [5]

Hence, the presence of the program image of actions in the subjects' consciousness creates favorable conditions for more effective mastery of the required labor operation (in the given case, operating levers) and accelerates its automatization and transformation into a habit.

The indices of accomplishing the experimental assignments by each individual subject illustrate this well. In the control group, the percentage of time of correctly moving the point reaches only 23% over the first five exercises, while 77% of the time consists of erroneous movement. Over the same five exercises, the average percentage of successful accomplishment of the assignments by the experimental group is 52%. Over the five concluding exercises, the working results of these subjects are even better. These results were an average of 82% of the time moving the red point exactly along the program line, which corresponds to an entirely adequate formation of

accuracy and coordination, and as a result of this of the speed of the working movements the hands of our subjects, which enter the process of operating the levers as components. With such indices, we considered that the appropriate skill was basically formed.

The composite graph (Figure 2) of the results of exercises of all our subjects who had mastered the skill of lever operation showed a line that quite evenly moved upward, without plateaus and interruptions. The graph of exercises depicting the individual character of formation of simulated operator skill in individual subjects (Figure 3) is an entirely different picture.

Although the general tencency to increasing the process of correctly accomplishing the assignment was quite convincingly demonstrated in all subjects, in the process of the long-term experiment, however, plateaus and even drops in their working success are encountered (we cite as an example the working indices of subjects G.S., D.B., and Yu.G.). These facts awaited an explanation. The objective conditions of our experiment were favorable. The device on which the subjects worked was in a separate room — the laboratory; they came to the experiment three at a time and these three were usually friends.

However, something influenced the uniformity of increasing the quality of the experimental assignments carried out by them. Our attempt to clarify the causes yielded results. As one could expect, besides the objective conditions (improvement of the experimental device, a favorable experimental environment, accessibility of the assignments subject to completion), other factors also had an effect /244 on the process of forming the siumlated operator skill. These were the subjective state of each subject, and the effect of events that occurred prior to his arrival at the laboratory.

We shall cite an example. We paid attention to the fact that the percentage of time of correctly moving the red point along the program line decreased in all our subjects in the 10th exercise. It happened that that day the school had been expecting a visit from

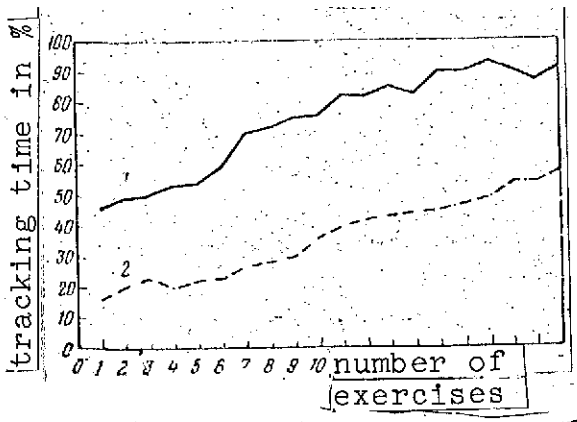


Figure 2. A graph of the time to correctly trace the trajectory of the object by subjects of the control (2) and experimental (1) groups.

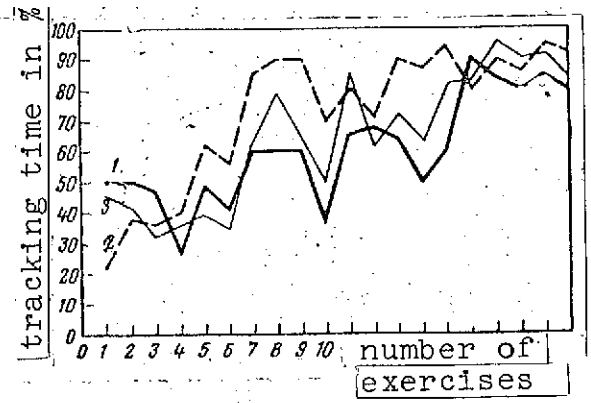


Figure 3. Curves showing formation of the sensory-motor skills of tracking. Individual graphs of the subjects are the following lines: subject G.S. (1), D.B. (2), Yu.G. (3).

the cosmonaut Yu. A. Gagarin and therefore the subjects came to the experimental session agitated, afraid they would be late to the meeting.

Obviously, the process of formation of any motor or other skills should take into account both stable individual characteristics of the subjects and their state at a given class. This state is reflected in the course of the exercises, but on the whole does not greatly retard the formation of the corresponding skill. /245

The data we obtained make it possible to assert that the process of independent subject determination of the program image of his future actions is a process that anticipates mastery of the appropriate skill and activates the psychological activity of the students. In its turn, this activation enables formation of labor motor skills.

Analysis of the experimental data shows that in an overwhelming majority of the subjects the formation of the image is inseparably linked with the use of verbalization, which emerges as a tool of thinking and summarization.

We were interested in verbalization only as a component of the inner intellecutal action occuring in the process of mastering a skill, and not in all of its functions.

Having identified and accepted the assignments suggested to them, certain subjects thought out each of their movements and each action in operating the levers. Very frequently they pronounced them aloud, which enabled us to judge the tendency and character of these discussions. Thus, in duscussing his actions in operating the levers, subject T.L. states to no one in particular: "If I move the lever here, how will the red light move? ...and this way...".

It was already mentioned above that when fixing the stopping coordinates of the white spot on the buttons, the subjects also pronounced the obtained data to themselves (information concerning the coordinate grid). Other subjects also resorted to pronouncing the data to themselves. In working, always internally active; they strive to establish and recall the relationship between the direction of hand movement and the direction of object movement along the coordinate grid on the screen. In talking aloud, they attempted to conceptualize, establish correct operation of the levers, and to plan their actions.

In their verbal reports, the students indicated that during the subsequent exercises in accomplishing assignments they had to intensively think how the hand should act in each specific case and how to coordinate the movements of both hands. Proportional to automatization fo the system of movements mastered by the subjects, the intensity of the latter decreases and verbalization becomes secondary.

We attempted more clearly to demonstrate the significance of identification and formation of the rules of lever operation for mastering the corresponding skills. With this goal, after the subjects' accomplishment of several exercises, part of the subjects had to formulate a rule of interrelationship of movement of the red luminescent point along the program line and of operation of the left or right lever. The requirement was not made on other subjects. It proved that most of the subjects whose attention had not been directed to determining the rule could not formulate it and even after quite prolonged exercises. They accomplished each exercise as a new one and the skill of lever operation formed very slowly in them. /246

This predominantly pertains to subjects of the control group, to whom the action program was given in ready form. The subjects who had attentively followed the coordination of hand movements in moving the levers and moving the luminescent point over the screen determined the rule of coordination which aided them more rapidly in mastering the required system of actions.

The data of this supplementary experiment confirmed the hypothesis of the positive role of inner and aural speech in the process of formation of labor operating skills. Similar data have also been obtained in investigations of the formation of motor skills made by Ye.V. Gur'yanov [6], L.M. Shvarts [7], and other investigators.

These authors demonstrated that the process of automatization of actions entering the structure of the given operational skill is a conscious process with mandatory participation of verbalization. The deeper the conceptualization and understanding of the system of actions mastered by the students, the higher the results of exercises. In a study, A.P. Puni [8] indicates that in the process of mastering motor skills, the participation of thinking is vital; such participation emerges in many ways. It is analysis, synthesis, comparison and summarization.

Consequently, in order to increase the effectiveness of training directed toward the formation of operating skills, activation of intellectual activity is obligatory. For this purpose, it is necessary to induce the students independently to verbalize during the solution of special intellectual problems, in addition to explaining the training-labor assignments, methods of their execution, and besides demonstrating methods of operation necessary for the given case. These problems can include understanding the rules of conducting any labor operation or understanding the operating principles of technical devices. /247

In conducting our experiments, we happened on an interesting fact. Independently of what type of labor attracts the subjects, all

twenty of our subjects were greatly interested in the experimentor's work (activating the experimental device, copying down indices from the counters, recording the working results of each subject).

The subjects who were free of accomplishing their assignments attentively learned which switches activated the current and which ones activated the program of actions. They were also interested in what the counters recorded and how the indices were recorded. After a short time, the subjects began to ask permission to stand behind the experimentor's control panel and turn on the switches and record the work of their comrades themselves. In those cases when they were permitted to do this, they attentively and accurately carried out the obligations they had voluntarily accepted.

In tracing the effect of independent subject determination of the image in the process of their formation of the skill of labor operation, we became convinced that the success of this type of activity also has a positive effect on their activity as control panel operators.

According to our data, timely and correct fixation of the stopping coordinates of the luminescent point (one of the components of control panel operator activity) was retarded in the first days of experimentation due to the absence of those qualities of those working movements in the subjects which general human capacity depends upon. They prove to be unprepared to execute accurate and rapid movements. They also fail in coordinating sensory and motor operations.

Nevertheless, execution of our experimental assignments required high accuracy of hand movements, speed, and obligatory coordination of working movements of both hands of the subjects. The experimentor strictly followed the execution of these requirements, and moreover, the counters entirely objectively recorded the slightest deviation from these as an error. Work under such conditions disciplined the subjects and forced them to be attentive and careful in executing their assignments, as well as to achieve good results.

The progress of our subjects in mastering the sensory-motor control skills was expressed in an unswerving increase in the coefficient of observation and a decrease in the percentage of errors made by the subjects in transmitting coordinates, which is indicated /248 by the data cited in the Table.

Apparently, the accuracy, speed and coordination of both hands formed during lever operation also transfer to the execution of other functions of control panel operators. Thus, mastery of the skill of control had a positive effect on the accuracy of perceiving the appropriate information, the speed of processing it, and the transmission of the accurate motor response — pressing the buttons in a timely and correct fashion.

RESULTS OF THE SUBJECTS' MASTERING SENSORY MOTOR SKILLS.

Order of exercises	4th	9th	14th	19th	20th
Percentage of correct responses	16	43	56	80	100

Hence, the subjects' execution of the assignments directed toward mastering the skill or operating control levers also has a positive effect on executing other operator functions. In the process of exercises with levers, the subjects partially acquired general capacity, which is an obligatory prerequisite of high productivity of any type of activity.

This means that the qualities of working movements of both hands that are formed in the process of manual labor are necessary for high quality work of the control panel operator, and are in addition to accurate perception of information and operational thinking.

CONCLUSIONS

1. In the course of the experimental investigations that were conducted by us, certain psychological conditions for increasing the effectiveness of occupational operator training were revealed.

2. It was shown that mastering operational skills occurs successfully under conditions that stimulate the students to an independent active analysis and summarization of current information with the goal of clarifying the signs and clearly imagining the integral images that are a model of the situation. Goal-directed determination of such an image, occuring by means of processing information, is due to using inner and external speech, which activates and improves the thinking of the student, accelerates the training process, increases its effectiveness, and enables the formation of strategies of anticipating the course of events. The use of such strategies make it possible for the operator to accomplish his functions by exceeding the behavior of the system he controls. /249

3. The independently identified operational image not only enables the formation of automatisms related to mastering sensory-motor skills, but also has a favorable effect on the accuracy of perception, increasing the rate of processing current information, as well as on correct decision making.

4. The subjects' execution of the assignments directed toward mastering the skill of operating control levers also has a positive effect on executing other operator functions. In the process of exercises with levers, the subjects acquired partial general capacity, which is an obligatory condition of high productivity in any type of activity.

REFERENCES

1. Lomov, B.F. Chelovek i tekhnika. (Man and Technology.) Izdatel'stvo LGU, 1969.

2. Oshanin, D.A., L.R. Shcherbak, and E.N. Konrad. The Nature of the Image-standard in the Process of Identifying Varying Objects. "Voprosy psikhologii", 1968, p. 5.

3. Oshanin, D.A. The Role of the Operational Image in Isolating the Information Content of Signals. "Voprosy psikhologii", 1969, p. 4.

4. Rubinshteyn, S.L. Bytiye i soznaniye. (Existence and Consciousness.) Moscow, 1957, p. 39.

5. Tezisov, Sb. A Collection of Theses, "Psikhologiya navchaniya tavikhorannya". (The Psychology of Learning and Education), Kiev, 1964, p. 198.

6. Gur'yanov, Ye.V. Skills and Actions. "Uchenyye zapiski MGU", Vol. 92, 1954.

7. Shvarts, L.M. The Problem of Skills and Their Interpretations. "Uchenyye zapiski Instituta Psikhologii," Vol. II, Moscow, 1941.

8. Puni, A.P. Ocherki psikhologii sporta. (Aspects of Athletic Psychology.) Leningrad, 1959.

CERTAIN ASPECTS OF THE PSYCHOLOGICAL ANALYSIS OF PROGRAMMER ACTIVITY

V.M. Bondarovskaya*

One of the most important problems arising today during the use /250
of computers is determining the conditions of efficiently distributing functions between man and the computer.

Psychological analysis is vital both as the very problem that must be solved by the aid of the computer, and the process of its solution.

Such analysis can be specifically directed toward separating the "computer" and "creative" (human) mechanisms of solution, and toward organizing problem solving by man and computer, which is an extremely pressing problem at present.

On the other hand, the problem of investigating the activity of people servicing the computer arises. This problem will also aid in noting ways of improving the computer in giving it certain functions of man and determining capacities for optimizing the conditions of its application. During this process, both the following regimes of computer use must be examined: the regime in which the earlier prepared program is relatively independently calculated by the computer, and the regime of joint problem solving my man and computer, the so-called dialogue regime. Each of these determines the problems (that differ significantly) that arise before man. And finally, operating the computer constantly requires solving the problems of seeking malfunctions.

In this study the subject will be the activity of the man who earlier prepares the program of operating the computer. A psychological study of this activity has become the order of the day with the appearance of the programmer profession, and remains a pressing /251

*Kiev, Laboratory of Ergonomics of NIIP

one today in connection with the necessity of optimizing the activity of professional programmers who are concerned, for example, with developing software computer support and with respect to the necessity of organizing the training and work of so-called computer consumers.

One can cite at least two aspects of such a psychological study. On the one hand, as has already been mentioned, is isolation of those human functions which can be given the machine and such a study of these functions as will permit their description and formalization. On the other hand, is a study of the existing methods of linking man with the computer both with respect to investigating the conditions of successful human mastery of existing means of communication, and investigating to what extent the existing means satisfy the capacities of man, the characteristics of communication of people among themselves, and developing the psychological requirements for input languages of automatic programming systems. The article will present certain results obtained during the psychological analysis of programmer activity and the principles of constructing a method of teaching the algorithmic language developed on this basis.

The activity of the programmer who services such a characteristic system for our time as the digital computer has been comparatively little studied. A large number of questions related to studying this type of working activity and methods of mastering it were for long the purvey of specialists in the given field without being in contact with psychologists.

There have been a number of methodological studies on improving the system of training programmers [1]. A list of courses which must be taken by specialists in the field of computer technology and programming as well as by persons participating in computer use has been compiled [2].

Several investigations have been conducted devoted to studying the activity of programmers, methods of selecting them, and methods

of effectively training them[3]; a special group to study the activity of persons performing maintenance on computers has been created at the Rand Corporation in Santa Monica [4]. This group has set the following tasks for itself: 1) determining the criteria for evaluating programmer activity; 2) developing effective tests for selecting programmers; 3) determining ways of effectively teaching programming. /252

The group considered the first problem the most urgent, since all of the subsequent ones can be solved on the basis of the data obtained during its solution. The group suggested determining the criteria for evaluating programmer activity by studying the structures of different problems solved by programmers, analyzing their activity, studying the difficulties they encountered, as well as the demands made on programmers in different organizations. It was suggested to use the obtained data as a basis for evaluation tests that then would have to be tried on different groups of programmers. The results of these tests were considered by the group to be expediently compared with the results of subjects' taking tests to check their capacities. The group hoped that establishing a correlation between them would make it possible to reveal the abilities and capacities necessary for successful programming and to note ways of contructing methods of selecting programmers and methods of effectively training them.

One of the first steps in the study conducted by the group on the activity of the programmer was an investigation undertaken by Scherwood and Arnold [5]. It was constructed in the following fashion. The authors went to 29 programmers and their supervisors with a request to make a detailed study of the qualities of the best programmer they knew. Of these 29 studies, the 140 most characteristic institutions were chosen and presented to 58 programmers and their supervisors so that the latter would note which of the institutions were most compatible with the characteristics of the best programmers known to them.

The authors statistically processed the obtained data and on /253

its basis isolated six factors characterizing the activity of the programmer. These included "Personal maturity and stability", "cooperation with other workers", "communication skills", "good background and independence", "professional maturity", "interest in work, and sincerity". The authors illustrate each factor by means of the statements that link it. Thus, for example, the 4th factor "good background-independence" was selected on the basis of the following statements: "Will program only when he truly understands the work and needs of the client", "well-founded", "documents his work", etc. And the 6th factor, "interest in work and sincerity" is based on the statements: "enthusiastic", "expends additional time and efforts on improving the program", "feels a sense of responsibility for the quality of his work", etc.

It is not difficult to note that the characterization of the qualified programmer compiled by Scherwood and Arnold is to a significant extent a characterization of qualified workers as a whole and inadequately takes into account the working specifics of the programmer. The results obtained by the authors show that it is inexpedient to compile a list directed toward studying any activity based soley on the opinions of specialists in the given field, without conducting a psychological analysis of the appropriate activity.

Data obtained when asking the opinions of specialists also served as a basis for F. Coss in his description of the programmer profile [6]. F. Coss' associates Datch and Shee studied an extensive range of problems related to investigating the examined form of activity: how programmers chose their speciality, what education they received, what attitude they had toward their profession, which personality qualities are considered vital for successful programming, which problems arise before the programmers, etc. With this goal, Datch and Shee compiled a special questionaire and circulated it among 549 programmers of various qualifications.

We shall examine the data cited by F. Coss. All the programmers who responded to the questionaire noted that the programmer should primarily have intellectual capacities, a good memory, the capacity

to express his thoughts, attentiveness to detail and the capacity to think logically. Additionally, he should have individuality and be /254
independent in his opinions. Part of the questioned subjects (21.5%) asserted that the qualified programmer should have the appropriate capacities and should have a serious attitude to his work, while others (36.6%) said that he should be able to think analytically, be serious, be able to learn rapidly and be able deeply to concentrate on a problem. 25.1% of those questioned wrote that in their opinion the qualified programmer is very representative; he has broad interests, a sense of humor and a high degree of individualism.

F. Coss does not draw any conclusions based on cited data and does not isolate characteristics in programmer activity. If he had done this merely on the basis of his cited data, obviously he would have obtained a characterization of the programmer similar to that compiled by Scherwood and Arnold, approximating the characterization of the qualified worker generally, and consequently, inadequately considering the occupational specifics of the programmer.

Hence, even the data cited by F. Coss indicates that compiling a questionaire directed to studying any occupational activity should be carried out on the basis of a preliminary psychological analysis of the appropriate activity.

A similar conclusion can also be drawn concerning a number of studies devoted to studying different tests for selecting programmers that were described in the survey of McNamarra and Hughes [7]. The characteristics of programmer activity cited by them and compiled by R. Canning [8] and C. Rush [9] were obtained, as in the previous cases, on the basis of questioning qualified programmers and their supervisors and inadequately consider psychological characteristics of programmer activity.

John Carr views the question of the programmer profile differently [10]. He proceeds from the assumption that there are 3 classes /255
of people involved in programming — the practical programmer, the programming instructor, and the investigative programmer. The latter

is concerned with finding ways of setting up problems not oriented to computer solution and with improving programming systems. Carr views the activity of the practical programmer from the viewpoint of what he should be taught. With respect to this, he dwells on achievements in the field of programming and on the problems that face programming, as well as the prospectives of changes in the programmer's profession. Carr cites a number of interesting concepts on who should be a programmer. These concepts, however, are the result of analyzing the activity of the programmer made by a specialist in the field rather than by a psychologist. Therefore, many aspects of this activity slip from the author's view. Additionally, he obviously considers a psychological study of programmer activity important, since withing the suggested structure of the "programming" course suggested by him he suggests including a section "programming psychology".

Peter Naur [11], one of the most famous specialists in the field of developing algorithmic languages, has interesting thoughts on how the characteristics of the programming language (the means of problem solving) influence man's thinking and his understanding of problems. He specifically notes that there is no problem outside the understanding of the means suitable for its solution. And if one considers the problem orientation of modern programming languages to be their characteristics, as a means of solution, then in the opinion of P. Naur, the greatest danger of the problem-oriented languages consists in their tendency to perpetuate the view of the problem as one suitable to the demands of the facility and thereby to cause sluggishness of the programmer's thinking.

S. Lavrov [12] indicates a number of factors related to the psychological characteristics in the activity of programmers' using computers of different generations. Specifically, he identified several of the occupationally important qualifications of the programmer (attentiveness, sharpness of wits, rapidity of reactions) that are necessary to him at the stage of laying out the program, /256
and indicated the collective nature of working on the computer in the era of using algorithmic languages, etc.

A.L. Jordan attempted to analyze the activity of the programmer statistically [13]. In an article on the objective criteria for evaluating programmer activity, he introduced a large number of criteria for evaluating the work of the programmer and gave formulas expressing their relationship. However, the natural basis for these formulas is the reference to the fact that they were obtained statistically on a reasonable basis. Moreover, from the article one cannot conclude that the author both determines and evaluates such criteria as "program optimization", "program complexity", "qualitative estimate of documentation", etc.

Hence, an examination of all these studies shows that the activity of the programmer has attracted the attention of a number of scientists. However, these investigations do not contain the results of psychological analysis of this activity, without which problems of the optimum organization of work, training, and selection of programmers cannot be effectively solved.

Investigations recently conducted by a group of Kiev psychologists and cyberneticists [14] do not suffer from these deficiencies. They specifically determine the problems that arise during the development of training systems based on computers designed for mass training of consumers. Moreover, a psychological analysis of the activity of the computer user was constructed and a method of teaching the COBOL algotithmic language was constructed. This method was laid as the foundation for compiling a program training aid on the COBOL language which underwent successful testing of professional programmers and students at the Kiev Institute of the National Economy [15].

To a certain extent, data obtained by the author in investigating the activity of programming personnel and for developing a method for effectively teaching the ALGOL-60 algorithmic languages were used when conducting the psychological study of activity of the computer user. The basic results of this investigation will be presented in the article.

The investigation was directed toward solving the problem of determining ways of effectively teaching programming. /257

At the first stage a preliminary psychological analysis of the activity of programmers was conducted. The foundations for this were observations of the work of programmers of different qualifications conducted by the author at the Institute of Cybernetics of the AN UkSSR, meetings with experienced programmers, and a study of the special literature. In the process of this analysis, qualities were isolated which can be included among the qualities necessary for successful programming, with a certain degree of probability, as were combinations of the most important of these qualities, difficulties that can arise during manual and automatic programming and during the mastery of input languages of automatic programming systems.

On the basis of this analysis, we compiled a questionaire that contained questions intended to clarify the qualities inherent to the qualified programmer and to assemble a series of facts necessary in studying the programmer's activity. After a series of questions, possible answers to them were suggested. The programmers who answered the questionaire had either to emphasize the possible answers that seemed most correct to them, or if necessary, to list the answers in the order of importance. If the possible answers after each question seemed inadequate to the programmer, he added everything that he considered necessary. The given questionaire was handed out to programmers of the Institute of Cybernetics of the AN UkSSR, the Institute of Gas Utilization of the AN UkSSR, the Institute of Geophysics of the AN UkSSR, and the Kiev Polytechnical Institute. In all, 63 programmers were questioned by the aid of the questionaire. In a number of cases, questionaires were filled out during a meeting. The programmers gave their opinion of their answers to the questionaire. Moreover, they were asked additional questions with the goal of clarifying certain characteristics of their activity.

In addition to the questionaires, we used a method of analyzing

programmer work products. With this goal, 29 programs of computer-solved problems and their work sheets were studied. An examination of these programs was also accompanied by meetings with the programmers. The goal of these meetings was to clarify the causes of errors, their character, and also to explain certain characteristics of programmer activity. All of the indicated data served as a basis for us to analyze programmer activity. The results of this analysis are cited below in connection with the examination of the programming process. This made it possible to /258
isolate a combination of characteristics of the studied activity and personality qualities necessary for successful programming. Since the given analysis was not directed toward solving all problems that arise when investigating programmer activity and is one of the first attempts psychologically to study this activity, the author does not pretend to have given an exhaustive description.

It is primarily necessary to note that in solving programming problems those means by whose aid the problem is to be solved actually exert an influence. The means of solution in this case are methods of presenting the solution of the problem in the form of discrete units of information and the rules of their transformation, as well as methods of recording the process of problem solving in a form "comprehensible" to the computer.

The orientation of the programmer to these means and the need for describing all of the smallest operations in problem solving for the computer gives his activity a specific character.

As follows from the results of psychological investigations, in solving a problem a person is not usually aware of the many operations he uses in the process of problem solving.

In striving to bring the conditions and demands of the problem into accord, he develops a strategy of solution (not always conscious) which determines his actions with respect to acquiring, storing and using information. If the adopted solution stratedy proves to ineffective in the course of problem solving, he shifts to a different and more effective one.

In the case of assigning problem solving to the computer, the programmer should describe all of the smallest operations that the solution consists of, as it were to peer within himself while solving the programming problem and reveal all the details of solution that he usually is not aware of. It is interesting to note that for those problems where this has proven to be possible (the solution algorithm exists), the programmer has transferred their solution to the computer. And for those problems whose algorithm is unknown, where "psychological" pathways of decision making emerge that are unconscious and represented in the form of a strict sequence of operations, this has not successfully been done. This is to a significant degree the kind of matter psychologists work on, which, for constructing a formalized description /259
of the process of decisions for this type of problem one must solve a number of methodological problems related both to setting up investigations and processing the obtained data.

But we shall now return to the activity of the programmer.

The character of activity of the programmer varies in cases in which he himself does not develop the algorithm of solution (the latter is known to him or can become known) and when he does develop the algorithm.

In a case in which the programmer develops the solution algorithm, preparation of the problem for its solution by the aid of the computer begins with selection of the numberical method of problem solving and composing the computation algorithm. In connection with this, the initial stage of preparing the problem includes the following processes: 1) analysis of the problem and selection of the numberical method of its solution; 2) composing the algorithm of solution of the problem; 3) evaluating the algorithm and possible errors in its solution.

This stage of preparing the problem is a mathematical analysis of the problem that can be carried out separately from the other stages. With respect to this, it is frequently not included in

the concept of programming and it is considered that programming itself is the second stage in preparation of the problem, and includes the following basic operations: 1) putting the problem-solving algorithm into a form convenient for recording in a form comprehensible to the computer; 2) recording the problem-solving algorithm in the language understandable to the computer; 3) controlling the correctness of composing the program.

Today, however, in the activity of the professional programmer the specific importance of this first, entirely mathematical stage performed by him increasingly grows. It is growing because an ever-growing proportion of simple problems in programming are now performed by persons interested in their solution. But the proportion of work of the professional programmer basically lies in solving complex problems that either require the development of an algorithm or complex work in putting it in a form convenient for recording in a language "comprehensible" to the computer. Therefore, with the goal of rationalizing the search for digital methods of problem solving and for composing algorithms, it is necessary to conduct a psychological study of the activity of the programmer during mathematical analysis of the problem.

We shall now dwell on an examination of the stage of programming itself. When the algorithm of problem solving is known and is adequately simple, the programmer immediately proceeds to record it in a language "comprehensible" to the computer. If the algorithm is complex and large, it must first be put in a form convenient for recording in the input language — one must compose a /260
logical diagram or block-diagram of the program. Composing the block diagram is a laborious process that is not easy even for experienced programmers.

The block-diagram of the program is usually constructed in the form of a system of rectangles and circles that are interconnected by means of straight lines depicting the order of accomplishment of the individual blocks. Within the rectangles the formulas of processes that are carried out in the given blocks are written,

while one writes the conditions under which they are accomplished in the circles.

The block-diagram is frequently the product of several attempts to approximate the full program plan. Changes in the diagram can be caused, for example, by the results of data exchange between the programmer and the computer when realizing any partial solution plan.

Successful solution of the problem before the programmer with respect to constructing the program diagram primarily requires conducting a careful analysis of the problem-solving algorithm directed toward reformation of the problem, which makes it possible both to examine the given algorithm in order to direct attention to details, and to the carefully thought-out logical operations necessary for solving the given problem, which man always gains intuitively — this must be described in detail to the computer.

If the programmer does not explain what might be done in all possible cases, in the course of running the program the computer will not give him the capacity to correct the diagram. The computer will unswervingly act in accordance with the diagram, will produce unexpected answers, stop, etc. Both the structure of the program diagram and the composition of the program itself depend upon the capacity to analyze the problem. It is not be chance that in answering the questionaire indicated above concerning the basic qualities necessary to the programmer that 37 of 59 programmers listed the quality of being able to analyze a problem first, while 8 others listed it second.

When constructing the block-diagram of the program, it is expedient to isolate the juncture points of converting data, in which the control operator can be placed and the intermediate results obtained. This is necessary for accomplishing control over the course of the program in the stage of programming.

Moreover, one of the most important problems solved by the

programmer in the process of constructing the program diagram is program optimization, i.e., creating a program diagram that will provide for minimum memory load of the computer, minimum problem solving time, etc. Solution of this problem predicates, on the one hand, the necessity of analyzing the algorithm of problem-solving, and on the other, the necessity of not using the first variation /261
of the program diagram to enter one's head, but the variation that provides for optimum use of the memory and operating time of the computer. In order to choose the best variation of the program diagram, the programmer must have the capacity to foresee how any particular diagram will be reflected in solution time and the volume of memory occupied, and to foresee the consequences of the actions he plans.

Hence, the process of programmer thinking during composition of the program diagram appears in a problem situation that is characterized by a conflict between the method of representing the algorithm of problem solving (the conditions of the problem) and the requirements to interpret this algorithm in the form of successive operations that can be carried out by the computer (activity requirements).

The structure of this problem situation is distinguished by a number of characteristics: the existence of a number of possible solution variations and the necessity of choosing the optimum variation; the sequence in solution steps; the necessity of isolating inverted operations; the absence of continuity between accomplishing actions and their result.

A significant characteristic of activity in compiling the block-diagram is the necessity of using already available methods of realizing algorithme, as well as the need for noting the possibility of employing standard programs. Here, a significant role is played by recognition of parts within a given algorithm for which programs already exist or for which block-diagrams have already been constructed. This recognition primarily occurs on the basis of the programmer's using his own past experience, knowledge con-

cerning solution of problems on computers, and standard subprograms.

Moreover, constructing the program diagram makes a number of demands on the combining components of thinking. The programmer should choose a stratedy of running the program satisfactory to the demands of the problem situation and determine all trends and conditions of accomplishing the program.

The accomplishment of all operations related to constructing a general diagram of the program makes serious demands on programmer attention as well. Dividing the algorithm into blocks, writing in the formulas in the necessary sequence and in a form convenient for programming, and thinking-through the control system of correctness of the written program require exceptionally intense attention of the programmer. /262

After compiling the block-diagram, it must be recorded such that the computer can automatically solve the problem. For this purpose, the program must either be written in the input language of the automatic program system or in the language of the computer in which solution will be carried out. In other words, at the given stage the programmer should translate the algorithm of solving the problem into the formal language acceptable to the computer.

The use of formal languages is one of the characteristics of programmer activity that makes its mark on many aspects of his activity. It also determines a number of demands made on the programmer. Presenting the problem solving program in a form comprehensible to the computer is the final goal toward which the programmer strives in carrying out transformation of the algorithm. It determines all of the operations solved by him and the scope of problems solved by the programmer.

Characteristics of programming languages are some of the means of problem solving standing before the programmer and obviously make an imprint on the entire process of problem solution. The use of these languages requires a certain restructuring of human

thinking both with respect to demands on uniformity of statement and delay of the effects of actions of the programmer, and with respect to limiting the means of such languages, to varying degrees remote from the multiplicity of means of the natural language.

To a great extent, the computer languages differ from the natural language. A number of limitations in programmer activity are related to the use of them. Programs written in computer codes usually include a large number of elementary operations and writing the commands appropriate to all these operations is a laborious and painstaking operation. During this process, the programmer must strive not to give any command, make no errors in writing addresses or command codes or to erase any results which could require the use of occupied memory cells, etc. during subsequent computer operations. Even accidental failure to observe any of the indicated requirements leads to errors that can cause incorrect program functioning. Therefore, the given stage, of composing the program requires intense programmer attention and causes a number of difficulties for him. As a rule, at this stage the programmer /263 makes the largest number of errors in the program. As was indicated above, with the goal of studying the character of errors made by programmers we conducted an investigation of 20 programs for solving problems on the computer and of their work sheets. Programs were examined written in the machine languages of the "MINSK-1" "M-20, and "KIEV". A study of these programs showed that the errors made during programming can be divided into two groups: a) errors made when putting the problem solving algorithm into a form convenient for writing it in a way understandable to the computer, i.e., when composing the program diagram; b) errors made when translating the problem-solving algorithm into the machine language. The basic number of errors made in the indicated programs (93%) were of the second group and only 7% of the errors were of the first group*.

*Certain errors made, when putting the algorithm in a form convenient for writing it in a way comprehensible to the computer, were a result of the fact that most of the problems analyzed by us were computational and are comparatively simple and short (up to 1,000 octuple commands). With respect to the more complex and larger programs, unfortunately, in most of the Kiev organizations that solve such problems, keeping records on errors made by programmers at the time of the investigation was not practiced.

What is the character of these errors? The largest group (66%) comprised the so-called miswritings due to incorrectly recording numbers, addresses, and occupied memory cells used in connection with this to correct sign-writing in the group command, the operation code, etc. Frequently, errors are encountered in organizing references to the subprogram (8%), in writing cycles (6%), and errors due to the fact that the programmer did not take into account some operating characteristics of the computer or certain details of running the given program (13%).

The table on page 319 contains data on the number and nature of errors made in the programs we examined.

Hence, on the basis of the cited data one can conclude that writing the problem-solving algorithm in the machine language makes serious demands on programmer attention (66% of the errors were errors of inattention and miswriting). This is also confirmed by the fact that 52 of the 63 programmers who responded to the questionnaire concerning basic diffuculties that arise during manual programming listed the difficulty caused by the necessity of always being attentive so as not to make errors in writing the program as one of the basic difficulties. In all these stages of programming, /264 the type of demands made on the programmer's attention are determined by such factors as: 1) difficulties in finding the consequences of actions included in the program; 2) difficulties due to the absence of continuity in determining errors; 3) delay in consequences with respect to the time of composing the program.

Writing the algorithm of solution in the algorithmic language is less difficult. Amelioration has also occurred because such languages approximate the living language and the language of mathematical formulas, and because systems of automating programming, whose input languages are algorithmic, have been given part of the programmer's work with respect to laying out the program.

Algorithmic languages and the systems of automatic programming as means of solution have exerted a significant influence on programmer activity. The work of the programmer was eased, there was

DATA ON THE NUMBER AND TYPE OF ERRORS MADE BY PROGRAMMERS IN COMPOSING 20 PROGRAMS OF A NUMBER OF COMPUTER ALGORITHMS WRITTEN IN A FORM COMPREHENSIBLE TO THE COMPUTER

	errors made when writing the program in the computer language, %			
errors made in composing the program diagram, %	miswriting	errors in referencing the subprogram	errors in writing cycles	errors due to failure to consider the operating characteristics of the computer or the program run
7	66	8	6	13

a decrease in the number of control operators provided for in advance, a decrease in time of preparing the programs, an increase in their scope, etc. It has become possible for persons interested in solving problems by the aid of the computer — the so-called computer consumers — to gain access to the computer. And professional programmers have been able to concentrate on complex problems requiring high worker qualification for their solution.

During this process, the increment in complexity of the problems being solved by the computer is due not only to the general amelioration of the process of programming resulting from adopting the algorithmic languages, but also to a determinable specialization of algorithmic languages. If the computer languages are specialized in the sense of their affiliation with a specific computer, then /265 the algorithmic languages are specialized with respect to those problems for whose program solution-writing they are intended. As a result of this problem orientation, success is attained in providing for means in the appropriate algorithmic language which permit the description of a problem of a certain type well and in adequately large units.

But the problem orientation of algorithmic languages acutally exerts an inverse effect on the person using them, as P. Naur has indicated. It causes a certain degree of stagnation of his thinking. The programmer begins to examine all problems he deals with from the viewpoint of the language in which he is going to describe

them. It is interesting that one can also discuss this phenomenon with respect to examining the course of discussions of a number of the scientists engaged in developing and adopting algorithmic languages.

Thus, in one of his studies, H. Simon directly describes the transcription languages and their modifications as the most suitable means of describing the solution of an extremely broad class of problems [16], considering it inexpedient to consider creating any new means.

Today, however, it has become necessary to solve a number of control, planning and design problems by the aid of the computer, for which a higher level of human communication with the computer is required as well as more improved algorithmic languages, in comparison with those that now exist.

One of the important prerequisites of developing these languages must be the results of psychological investigations of the use and mastery of existing programming languages, the process of solving the appropriate problems, means of depicting them in the natural language and the language of mathematical formulas.

Finally, the program is composed. Now it must be checked in the most careful fashion. The stage of finding and correcting errors made in the program is extremely important, since many problems solved on the computer are extremely important ones and expensive equipment is constructed according to their results, or complex experiments are conducted according to them.

The first stage in checking the program is controlling it prior /266
to input. This means that after composing the program, the programmer (even better if it is another programmer, and not the one who composed the given program) should carefully read it through and attempt to find errors in it, specifically, various miswritings that are often encountered in programs. But carrying out such control does not give complete confidence that the obtained program

does not contain errors. Therefore, prior to carrying out computer computations according to the given program, the program must go through the stage of layout, whose goal is to isolate all errors existing in the program and to demonstrate the correctness of the program. The former is necessary so that the programmer can be convinced that the program will run from beginning to end and that the computer will not "lock-up" due to some incorrectly written command. It is then necessary to ensure that the program is run in accordance with its block-diagram (the logic diagram), i.e., that the individual parts of the program are run in the necessary order. After this the programmer should check to see how the separate components of the program are accomplished, i.e., those that realize more or less indipendent partial algorithms. Following automatic layout of the parts, complex layout of the program is carried out; the task of complex layout is to check the correctness of the total program structure. During this process, it is necessary to check possible ways of running the given program. During both automatic and combined layout, the results obtained on the computer are compared with the manual control variations that have been read through.

The final stage in laying out the program is the control computer computation of actual variations of the problem, which makes it possible to ensure that the program correctly functions and provides the necessary accuracy of computations. After all the control variations have been correctly solved, the correctness of the program is considered proven and computation of the problem begins.

During manual programming, layout is usually carried out by the programmer himself at the computer control panel. In order that layout be successful, the programmer must be able to analyze the situations encountered during the verification computations, and must isolate on the basis of this analysis the cause of appearance of any results, immediately encompassing all aspects of the developed situation, rapidly analyzing it, finding existing errors, /267
and finally, finding the error. In other words, when seeking out errors, the programmer must thoughtfully develop a strategy for finding error, for which purpose he must analyze the developed

situation, construct a hypothesis of the cause of the given error on the basis of the analysis, determine ways of checking the hypothesis, comparing the results of the check with the existing data, and further, in case of correctness of the hypothesis, eliminate the error, but in the case of its incorrectness, compose a new hypothesis and check it.

In this case, the activity of the programmer by its nature is near that of the operator in an automatic control system. A significant role begins to be played by the speed of the programmer's processing the incoming information, the method of its processing, etc. In connection with this, the given stage of preparing the problem for computer solution makes a number of demands on the volume, distribution, and redirection of programmer attention.

Hence, the stage of laying out the program is exceptionally laborious and requires that the programmer master certain skills and capacities. It is demonstrative that 36 of the 63 programmers who responded to our questionnaire concerning basic difficulties in manual programming noted among these the difficulties due to checking program layout.

During the use of automatic programming systems, as has already been mentioned, a significant part of the work in program layout is given the computer. The programmers have stopped working at the computer control panel. But then it began to be demanded that they compose detailed instructions for running the program. With respect to this, the demands due to preliminary planning of computer actions and foreseeing the consequences of actions provided for in the program have increased, while demands on the dynamic components of programmer thinking have diminished.

What qualities must the modern programmer have?

The programmer should have the capacity independently to make decisions at different stages of composing the program, should have a certain flexability and dynamic nature of thinking, should be able to structure objects, and isolate the hierarchical rela-

tionship between them. Flexability of thinking permits him to overcome the interfering effect of decisions made earlier, if necessary, with respect to choosing new variations of solution. High demands are made on the dynamic nature of thinking by the process of program layout: the programmer must rapidly reprocess| data received from the computer and rapidly make decisions on the causes and locations of errors, etc. /268

The profession of the programmer also makes demands on his memory, attention, self-control and perception. Specifically, programmer inattention leads to errors in the program, as has been stated. The appearance of errors decreases the effectiveness of programmer work and increases period of time required to prepare the program due to the increase in the amount of time lost on finding and correcting errors. It is characteristic that 9 of the 59 programmers who responded to our questionnaire on the qualities important to the programmer chose attentiveness as the most important quality required by the programmer, while 13 put it in 2nd place. At the same time, 4 programmers considered accuracy the most important quality required by the programmer, and 8 put it in 2nd place.

In order to successfully program, it is also important to have a good memory, specifically a verbal-logical memory. Having a good memory, the programmer is better oriented in the programs he composes, seldom references the program diagram with respect to portions of the program already programmed, is more likely to have the capacity to use portions of problems he has already solved in composing the program, etc. All this permits him to decrease the time and effort spent on composing the program.

A number of requirements are also made by the programmer profession on human perception. The successfulness of problems solved by the programmer that develop during layout depends on the characteristics of programmer perception.

Such qualities as stability and goal-seeking activity are extremely important for the successful work of the programmer. These

qualities are necessary to bring composition of the program to a conclusion; this frequently causes difficulties and contains many monotonous operations.

Finally, preparation of the program of computer operation is a long-term, laborious process whose successful accomplishment makes a number of demands on the personality qualities of computer programmers. Clarification of these demands is important for constructing both methods of effective programmer training and methods of programmer selection.

We made an attempt to use the results of psychological analysis of programmer activity we obtained to construct a method of effectively training programmers. Proceeding from the fact that one of the basic characteristics of programmer activity is the need for writing the algorithm of solution in a formal language accessible to the computer, we concentrated our efforts on finding methods of /269
forming the capacitities to write algorithms in the input language of the system of automatic programming in the students.

As is known, at the basis of most algorithmic languages lies the formulo-verbal method of writing algorithms, i.e., the algorithms of solving problems are written by the aid of words and formulas in accordance with the rules of syntax of the given language. The mathematical formulas bring the algorithmic languages closer to mathematical symbols (the language of mathematical formulas), while the words taken from any living language, as well as the presence of a fully determinable syntax bring them closer to the living languages. Therefore, when determining ways of effectively teaching algorithmic languages, we proceeded from the need to consider the character of these languages, using certain principles of psychology and methods of teaching mathematics and living languages, where this proved justified. Moreover, we proceeded from the possibility of using certain aspects in common for mathematics and language for these goals.

One of the central factors of effectively mastering input lan-

guages is successful mastery of the capacity to write the algorithm of problem solution in a given language. The solution to this problem predicates determing the conditions of the students' mastery of the lexicon and acquiring the skills of selecting and applying the lexical units of the studied language, mastery of the system of concepts specific to the given language, methods of intellectual activity, certain characteristics of the given language, and acquiring a number of skills and capacities that are components of the formative activity.

When isolating the components of the capacity to write the algorithm in the input language, we proceeded from a general model of the input language and the hierarchy of basic structures of ALGOL-60 algorithmic language, which served as the material of our investigation.

By general model of the input language, we mean the general description of those means of writing algorithms that permit writing algorithms comprehensible to the computer, and that by their structure reflect the most significant links and relationships inherent to input languages.

When constructing the model, a number of input languages were analyzed (ALGOL, the Address language, COBOL, UNICOD, FORTRAN, IT, MAD, etc.). The model was a diagram that included the basic structures and means whose description requires use of the input language. During composition using the specific program language, the diagram can be converted into a set of structural models related to the /270
appropriate summarized content and capable of being filled in with various lexical material. By the aid of this model, the ALGOL-60 language was analyzed and a hierarchy of the basic structures of this language was constructed, serving as a basis for isolating the components of the capacity to translate the algorithm from the language of mathematical formulas and the native language to ALGOL-60.

During the analysis of the ALGOL-60, division of languages into tiers (orders, levels) and certain principles of modeling specific

structures of the language were used as well as the relationships between them and known from the psychology of teaching foreign languages; these are similar to those employed for analyzing living languages.

With the goal of determining ways of constructing an effective method of teaching algorithmic languages, an experimental investigation of the process of teaching school children and students the ALGOL-60 training language was conducted. In connection with the fact that the analysis of existing methods of teaching such languages has shown that these methods inadequately take into account the psychological principles of mastering such languages, we made an attempt to develop a process of teaching the algorithmic language under conditions of using the traditional method and under conditions of employing a method directed toward forming in the students a generalized capacity to write algorithms in the input language, and to isolate on this basis the principles and conditions of successful mastery of the algorithmic language. When developing the given method of training, we proceeded from the fact that mastering the concepts needed to master the input language must occur on the basis of actions related to operating the appropriate training material. On the other hand, the mastery of these concepts should be intimately linked with mastering the lexical units of the studied language appropriate to them. During this process, we considered it possible to use the principle of modeling these structures by means of their various lexical content for the purpose of mastering the structures of the given language. Moreover, we considered that this principle can also be widely used when forming the necessary skills and capacities for mastering the input language. Mastery of the latter, specifically the capacities to use different operators of the studied language, should occur on the basis of solving a number of practical problems directed toward analyzing the algorithm and translating it into the given language. The solution of such practical problems can provide for continuous mastery by the students of all components of the capacity to write /271
algorithms in the studied language. These problems should be such that the solution of each of them makes it possible to formulate

a general capacity to write algorithms in the input language and a general approach to solving problems in selecting and organizing the means of the language used in the given case and necessary for writing a given algorithm.

Moreover, in developing the method of forming this general capacity, we strove to overcome the interfering effect of the specific language on the approach of our students to programming problems, as well as to form in them a more or less broad view of the means of depicting the problems solved by the aid of the computer, on the basis of the general model of the input language.

The experimental investigation of the principles of mastering input languages and the ways of rationalizing teaching of input languages provided for the solution of the following problems: 1) a psychological study of the principles of forming the capacity to write problem solving algorithms in the input language under conditions of using different methods of training in senior classmen and students; 2) a psychological study of the difficulties of mastering the input language under conditions of using different methods of training in senior classmen and students; 3) determining the conditions of effectively forming the ability to write algorithms in the input language in students.

For solving the studied problems, we conducted an experimental study of the ALGOL-60 algorithmic language on 2 groups of 12 people each, consisting of students in the 11th grade of School 53 in Kiev; upon graduating from the school, these students received a specialty rating of "computer programmer". We also used 2 groups of 7 people each consisting of students from the 5th course of the Kiev Polytechnical Institute, who would be specialists in the field of computer technology.

The basic indices of mastering the studied language were the following; 1) the results of the students' accomplishing actions on the basis of which concepts were acquired; 2) the results of the students' accomplishing control assignments on writing algorithms

and their parts in the studied language; 3) the students' responses to control questions and the measures necessary to aid them in making a correct response; 4) the results of the students' accomplishing those control assignments in writing algorithms in the studied language and in comparing the ALGOL-60 and MAD languages in the subsequent stage of training.

The first stage in training all groups was checking the fullness and evenness of mastering the preliminary knowledge, skills, and capacities that lie at the basis of forming the capacity to write algorithms in the input language.

One group of school children and one group of students were the control. They used the method of teaching the input language that presently exists. The students were given prepared knowledge and samples of actions in accomplishing examples of writing ALGOL programs, after which they independently carried out a number of assignments in employing this knowledge.

Two other groups were experimental. The goal of training these groups was clarification of the psychological conditions of effectively teaching the algorithmic languages. Training in these groups was directed toward forming a common capacity to translate problem solving algorithms from the language of mathematical formulas and the native language into the algorithmic language. At the basis of the training method employed in the experimental groups were the theoretical prerequisites presented above.

The students of the control and experimental groups carried out the same control assignments over the entire course of their training. This made it possible to compare the results of the students' mastery of various groups of structures of the studied language and the relationships between them, as well as the individual components of the capacity to translate the algorithms into the studied language at each training stage. Accomplishment of the control assignments and the assignment on comparing the ALGOL-60 and the MAD languages made it possible to determine not only to

what extent formation in students of various groups of the examined capacity occurred, but also what capacities of transferring this capacity to other algorithmic languages existed.

The results obtained during training of the control groups of students showed that teaching the input language under conditions of the existing method of training does not ensure effective mastery of the language by the students. When teaching the algorithmic language under conditions of existing method of training, a number of difficulties arise in the students. These primarily include difficulties in mastering the lexicon of the language and skills of using its lexical units, which mainly pertain to difficulties linked with the psychological dissimilation of concepts already known to the students (or near those already known to them) and the form of their linguistic expression, and the difficulties related to mastering concepts new to the students.

On the other hand, a number of difficulties appear in the students with respect to mastering methods of intellecutal activity necessary for accomplishing algorithm writing in the input language.

/273

In composing the program, the students of the control groups strove to follow the example given them. Every necessity independently to accomplish actions led to the appearance of difficulties. The results of the students' of the control group accomplishing the control assignment demonstrated that students taught in accordance with existing methods have a weakly generalized capacity to write problem-solving algorithms in the input language and extremely slight capacities of translating.

On the whole, the analysis of the results of teaching the control groups of students and the difficulties they encountered under the conditions of the existing method of training showed that for successfully mastering the input language of the system of autoprogramming, it is necessary specially to form in the students a number of concepts and capacities of their use, especially to organize the students' acquisition of lexical units of the studied

language, and to form the appropriate methods of intellectual activity [17].

The results of training the experimental groups showed that learning the input language on the basis of a common model of the input language and based on comparing the studied language with a given model existing in the course of the entire training process make it possible to create certain conditions of successfully forming a common capacity to write algorithms of problem-solving in the input language and permit the students' development of thinking.

Learning the lexicon of the input language based on actions in operating concepts lying at the basis of the appropriate lexical units and on modeling structures of the given language by means of their varied lexical content make it possible significantly to increase the effectiveness of the students' mastery of components of the ability to write algorithms in the input language, based on mastery of the lexical units of the language.

Formation in the students of intellectual operations lying at the basis of the ability to write algorithms in the input language, structured on the basis of the students' solving a number of practical problems requiring the accomplishment of these operations, and based on modeling the relationships between the concepts representing the essence of these operations, create certain conditions for overcoming the difficulties of mastering methods of intellectual activity necessary for writing the algorithms in the input language. As a rule, in compiling the programs, the students of the experimental groups did not follow examples, but approached the assignment creatively, creating original and often optimum programs.

It is characteristic that when carrying out the assignment to compare the studied input language with the MAD language, which was planned to provide for transfer of the capacity to write algorithms formed in the students to another input language, in view of the weak commonality of this process in the students of the control

groups, such students coped poorly with the indicated assignment (only one of them was able to complete it).

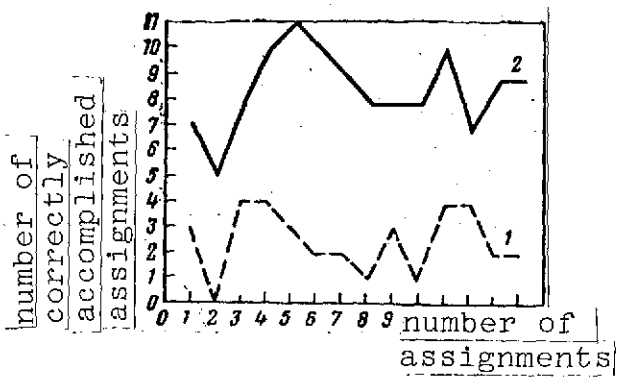
With respect to the students of the experimental groups, the given assignment was entirely completed by 75% of the school children and 71% of the students. The remaining students coped with it at a level of 65%. All this indicates that in the experimental groups, the degree of commonality of the capacity and ability to transfer the given skill to the new input languages were significantly heightened in comparison with the control groups.

The figure shows a graph of the relationship of the number of correct responses of students of different groups of school children, depending on the method of training. As one can easily note, students of the experimental group coped significantly more successfully with the control assignments than the students of the control group.

The same conclusion can also be drawn by determining the statistical characteristics of the data obtained for each group of subjects, and also by using the results of combining the samples of the control and experimental series.

These data show that students of the experimental groups carried out significantly more assignments without error (average value of the number of correctly accomplished assignments — 9.6), than students of the control group (average value 2.7). Similar results were obtained by us when teaching groups of schoolchildren of the same class (12 people) and groups of students of the same course (8 people) by the aid of programmed training devices, whose basis was the method of teaching the algorithmic language we suggested. The students of these groups reached approximately the same level of mastery of the input language as the students of our experimental groups.

Hence, the results of the investigation we conducted showed that the successfulness of mastering the programmer profession sig-



Graph of the relationship of the number of correct answers of the students and methods of training them.

1- control group
2- experimental group

noficantly depends on the perfection of methods of teaching programming. Constructing effective methods is impossible without conducting psychological analysis of programmer activity, and without revealing its psychological characteristics.

The psychological analysis of programmer activity ~~was conducted~~ showed that one of its basic characteristics is the need to employ formal languages. ~~Therefore, determining the conditions of successful~~ formation of the capacity in the students to write algorithms in a formal language comprehensible to the computer is one of the most important questions that appear in determining ways of constructing methods of effectively teaching programming.

In determining ways of effectively mastering the capacity to write algorithms in the algorithmic language, it is expedient to proceed from its similarity to the living languages and the language of mathematical formulas, and to choose certain psychological principles of mastering foreign languages and mathematical symbols ~~where justified. The use of these principles~~ in teaching the algorithmic language, ~~and in teaching such a language based on the~~ general model of the input language make it possible significantly to increase the effectiveness of its mastery and permit the development of thinking on the part of the students.

REFERENCES

1. See for example: Glushkov, V.M., A.M. Dovgyallo, V.P. Semik, Ye.L. Yushchenko. K voprosu o programmirovannom obucheii programmirovaniyu. (The question of programmed training in Programming) Kiev, 1963; V.M. Monakhov. Methods of teaching a course, "Teoriya Matematicheskikh mashin i osnovy programmirovaniya" (The Theory of Computers and Fundamentals of

Programming in the Mid-level General Educational Polytechnical Occupational School Specializing in Mathematics) Author's abstract of Candidate's Dissertation, 1963; F. Gruenberger, Secondary Education. "Datamation", Vol. 8, January, 1962; G.M. Silvern. Programmed Instruction for Computer Programming. "Computers and Automation:, Vol. 12, No. 3, 1963.

2. Curriculum of Recommendation for Academic Programs of Computer Science. "Communications of the ACM", Vol. 11, No. 3, 1968.

3. Carr, J.W. III, The Future of Programming and Programmers. "Comput. Bull.", Vol. 8, No. 1, 1964, Fr. Coss. A Profile of the Programmer. "Communications of ACM", Vol. 6, No. 10, 1963, H.R.J. Grosch. Computer people and their culture. "Datamation", Vol. 7, No. 10, 1961; W.J. McNamarra and J.L. Hughes. A Review of Research on the Selection of Computer Programmers. "Pers. Psychol.", Vol. 14, No. 1, 1961.

4. The Computer Personnel Research group. "Datamation", Vol. 9, No. 1, 1963.

5. Scherwood, H.P. and H.P. Arnold. Identifying Programmer Behavior. "Datamation", Vol. 9, Jan., 1963.

6. Coss, Fr. A Profile of the Programmer. "Communications of the ACM", Vol. 6, No. 10, 1963.

7. McNamarra, W.J. and J.L. Hughes. A Review of Research on the Selection of Computer Programmers. "Pers. Psychol.", Vol. 14, No. 1, 1961.

8. Canning, R.G. Installing Electronic Data Processing Systems. New York, 1957. (Cited according to W.J. McNamarra and S.L. Hughes. op. cit.).

9. Rush, C.H. The Selection of Computer Programmers. An Unpublished Study in 1958-1959 at Standard Oil Company (New Jersey) (Cited according to W.J. McNamarra and J.L. Highes. Op. cit.).

10. Carr, J.W. III, The Future of Programming and Programmers. "Comput. Bull", Vol. 8, No. 1, 1964.

11. Naur, P. The Place of Programming in a World of Problems, Tools and People, Proceeding of the IFIP Congress, 1965.

12. Lavrov, S. Computer Software. "Nauka i zhizn", 1971, p. 1.

13. Jordan, L.C.R.V. Programming Talent can be Measured. "Datamation", July, 1962.

14. Glushkov, V.M., L.P. Babenko, A.M. Dovgyallo, Ye.I. Mashbits, A.A. Stogniy and Ye.L. Yushchenko. Teaching Programming by the Aid of Digital Computers, Parts I,II. In the collection: "Trudy nauchno-tekhnicheskogo semiara "Primeniye tsiforvykh vychislitel'nykh mashin elya obucheniya programmirovariya". (Transactions of a Scientific-Technical Seminar, "The Appli-

cation of Digital Computers for Teaching Programming") Kiev, 1970.

15. Babenko, L.P., S.N. Berestovaya, V.D. Rogach, Ye.L. Yushchenko, V.V. Andriyevskaya, G.A. Ball, V.M. Bondarovskaya, and Ye.I. Mashbits. Programmirovannyy uchebnik po yazyku KOBOL I rezul'taty yego eksperimental' noy proverki. (A Programming Textbook on the COBOL Language and the Results of Its Experimental Check).

16. Simon, H.A. The Use of Information Processing Languages in Psychology, In: "Les Modeles et la Formalisation du Comportement" (Behaviour Models and Formalization), Paris, 1967.

17. Bondarovs'ka, V.M. The Character of Difficulties that Arise during Mastery of the Algorithm Language. In the collection: "Psikhologiya', (Psychology), No. 4, Kiev, 1967.

N75 17957

THE REACTION OF THE CARDIO-VASCULAR AND SYMPATHICO-ADRENAL SYSTEMS TO INTELLECTUAL ACTIVITY WITH EMOTIONAL STRESS

L.I. Tomashevskaya*

The study of the work of the operator professions, which are /276
characterized by an increase in intellectual and emotional stress of the worker, requires a combination approach and must be carried out jointly by psychologists, physiologists, hygenists, sociologists, economists and other representatives of the human sciences. The mission of our investigation was a study of the activity of the cardio-vascular and sympathico-adrenal systems during the accomplishment of emotionally tense intellectual work.

Although this question is clearly inadequately illuminated in the modern literature, in teachings on the adaptation-trophic role of the sympathetic nervous system in the organism (L.A. Orbeli [1]), on homeostasis (V. Kennon [2]), and the adaptative syndrome (G. Sel'ye [3]) in modern psychopharmacology, the idea of the important role of the sympathico-adrenal systems in the mechanisms of emotional reactions runs like a red thread.

According to the concept of L.A. Orbeli, the role of the sym- /277
pathico-adrenal factors consists in a constant adaptation of the intensity of the metabolic processes and the physico-chemical relationships in the tissues to the functional demands of the given moment.

V. Kennon showed that unity and constancy of the inner medium of the organism are supported at the price of complex and multiple processes, where an important and almost universal role belongs to the sympathico-adrenal system.

According to the theory of G. Sel'ye, under the effect of exposure to various stimuli, two types of reactions appear in the

---

*Kiev, Scientific Research Institute of Occupational Hygiene and Occupational Diseases.

organism — the specific and the non-specific. The state of the organism evoked by the non-specific reaction appears stereotypically as the result of the effect of different pathogenic factors which G. Sel'ye termed "stress". He attributed an important place in the appearance of this reaction to the adrenal cortex, which is stimulated by the sympathico-adrenal system. The latter also affects the hypophysis' treatment of ACTH, as well as the effect of the secreted corticosteroids on the periphery.

In the opinion of E. Gel'gorn and G.S. Lufborrow [4], under conditions of emotional stress the reticular formation is activated through the corticofugal pathways from the neocortex and limbic cortex; from the reticular formation impulses proceed to the posterior region of the hypothalamus, which affects the hypophysis' secretion of ACTH.

In observations of healthy people in different emotional states, a significant change in the sympathico-adrenal system was detected that was expressed in an increase in the secretion of adrenalin and the appearance of the state of alarm. Secretion of noradrenalin increases in the state of aggression, anger, or in situations that produce psychological stress.

Experience accumulated by psychopharmacology confirms the presence of a relationship between the effect of medications that stimulate the functions of the sympathic-adrenal system and human emotional state.

Preparations that cause a decrease in secretion and inactivation of noradrenalin cause calm or depression.

In dwelling on the mechanism of effect of the psychoactive drugs, Eiduson [5] notes that "only a study of the metabolism, means of storage and function of the biogenic amines will aid in clarifying the molecular substrates of the emotional disorders."

P.K. Anokhin [6] points out that any type of negative emotion /278

is linked with mobilization of the adrenergic substrates of both the brain and the peripheral apparatus. P.V. Simonov [7], Yu.A. Makarenko [8] and N.G. Mikhaylova [9] indicate that emotional reactions are characterized by a certain type of interaction of the sympathetic and parasympathetic factors, and that the specific importance of the latter depends on the degree of specifics of these emotional reactions.

In physiology and in the clinic, more and more data are being accumulated on the role of neuro-emotional stress in the origin of pathological states. Thus, there are adequate data on the increased rate of hypertonic disease among persons whose professional activity is accompanied by significant neuro-emotional stress. These data confirm the neurogenic theory of hypertonic disease developed by G.F. Lang [10] and A.L. Myasnikov [11], according to which the negative emotions cause states of pathological inertness or stagnation of the processes of stimulation of the neural apparatus that regulate the blood pressure as the result of overstress.

Coronary disease, myocardial infarct, and atherosclerosis are also widely distributed among those occupational groups whose working processes are characterized by high neuro-emotional stress.

The role of intellectual overstress in the appearance of the psychological disorders is indicated by I.A. Polishchuk, P.V. Biryukovich [12], V.N. Vashetko, L.Ye. Koroleva [13] and others.

P.K. Anokhin [14] considers that processes of excitation of the hypothalamus and reticular formation, i.e., the region of the central nervous system with the greatest representation of adrenergic elements, have great inertia and gradually become a unique epicenter increasing excitability both in the ascending (formation of cortical hypertension), and in the descending direction in the form of eased and increased mobilization of the vegetative components. Individual characteristics of the organism, elevated sympathetic activity under conditions of calm, the presence of previous diseases, smoking, the hereditary factor, corpulence, hypo- /279

dynamia, etc., have great significance in the transition of the normal physiological emotional reaction into the pathological one.

In connection with the material above, interest doubtless attaches to studying the character of the effect of emotional-stressful intellectual activity on the functional activity of the sympathico-adrenal system, as well as to establishing the correlation relationships of the state of the latter and the activity of the cardio-vascular and central nervous systems. Reports in the literature on this question are few, particularly with respect to investigations of these functions in operators over the course of the working day under industrial conditions. The results of investigation on the noradrenalin metabolism are also contradictory. The observed changes in functional activity of the sympathico-adrenal system, in most cases, have not been compared with the condition of the other systems. Pekkarinen at al. [15] investigated the content of catecholamines in the urine of students during examinations. An increase in the excretion of adrenalin was observed and the degree of increment depended upon the subject of examination. Thus, the excretion of adrenalin increased from 3.6 to 8 ng/min in biologists, up to 15 ng/min in physicists, and up to 21 ng/min in mathematicians. Among women, a tendency toward a lesser increase in the excretion of adrenalin was noted than in men. Excretion of noradrenalin did not increase. An increase in the excretion of both catecholamines during examinations was also observed by F.I. Grishko, A.N. Ratushnaya [16], I.G. Dlusskaya et al. [17], who detected an increase in the excretion of adrenalin among subjects working at an experimental control panel. Frankenhasser and Post [18] found an increase in the excretion of adrenalin ranging from 6.8 - 8.4 to 11 - 15 ng/min among subjects during intellectual stress over a 1 hour period. In the subjects who had been informed of the conditions of the experiment, the data of adrenalin excretion increased. Deprivation of sleep on the eve of /280
a stressful eight-hour working session caused a two-fold increase in the excretion of adrenalin and noradrenalin, in comparison with the norm. At the same time, an increase in the ambient temperature and the inclusion of muscular work did not lead to significant

changes in the excretion of catecholamines, in comparison with the control. Grivel et al. [19], in creating emotional stress during intellectual activity in an experiment by employing intensive industrial noise (100db) and a flashing light found an increase in the excretion of both catecholamines in subjects; simultaneously these authors observed an increase in the plasma content of neutral lipids and free aliphatic acids.

Patkai [20] notes a direct relationship between the success of accomplishing an assignment and the level of noradrenalin excreted with the urine in subjects who carried out an assignment that required concentrating attention and distraction from incidental noise.

Kato Juichi et al. [21] measured the excretion of catecholamines in subjects 20-29 years old and 47-55 years old during mental calculation over a one-hour period. The authors note an increase in the excretion of adrenalin with the urine, which was more extensive in the younger group. The amount of noradrenalin did not significantly change. A positive correlation relationship was found between the excretion of adrenalin and the number of calculated figures.

Euler [22] indicates a 3-4-fold increase in the excretion of adrenalin in pilots during flights. An increase in the excretion of noradrenalin was observed in some of them. Interesting data have been presented by this author in studying the functional condition of the sympathico-adrenal system in astronauts. Over four days before the flight, the excretion of adrenalin comprosed 24.7 mq per 1 part creatinin, which is a good illustration of the stress caused by misgivings; 30 minutes after the beginning of the flight /281
— 33.4 mq, 3 hours after landing — 27.4 mq per 1 part creatinin; the return of adrenalin excretion to the normal figures was observed 45 hours after the flight.

Lowi [23] indicates that in the telephone operator the more stressful work is accompanied by an increase in the excretion of noradrenalin. Among office workers, excretion of catecholamines was higher on piece-work payment days than on days when they were paid by the hour. Disruption of the diurnal rhythm of catecholamine excretion was observed in telegraphers by Ye.V. Podoba [24].

We investigated the functional condition of the sympathico-adrenal and cardio-vascular systems during the operator's work on an experimental control panel in different working regimes.

The experimental investigations were constructed on the EMO-3 device designed by Ye.A. Mileryan [25], and especially created for studying the effect of the emotiogenic factors on the operator's intellectual activity. The subject's work on the device consisted in observing an instrument panel, recording readings of instruments according to an assigned program, making appropriate decisions, and carrying them out by means of earlier known differentiation of lever movements. The device provided for an assortment of emotiogenic stimuli (light, sonic, electrocutaneous) which either separately or in combination could be activated by the investigator during the subject's work on the device. We used the electrocutaneous stimulus as an emotiogenic factor. The stimulus was activated automatically if the subject gave an incorrect response. The subject panel consists of an instrument panel and another panel having two levers. Eight indicator dials and a lighted screen for presenting schedules of reading the instruments are on the instrument panel. Each of the levers on the panel can be placed in one of five positions. Each of the positions corresponds to a certain number: from 1 to 5 for the right lever and from 6 to 10 for the left. These levers are used for entering a response during the solution of problems. The experimentor's panel has a switch for connecting the circuits, a work mode switch, a stimuli rate presentation indicator, a table of readings of correct response, a correct response counter and an error counter. /282

The functional condition of the sympatico-adrenal system was studied by means of determining the rate of excretion of free adrenalin and noradrenalin by the fluorometric method of V.O. Osinskaya in the modification of A. M. Baru. The urine for catecholamine analysis was collected in two portions — the preexperimental and the portion over the period of intellectual work. In view of the pronounced cyclicity in activity of the endocrine glands, investigations on the device were carried out at a strictly determined time of the day and urinalysis in calm was carried out at the same hours.

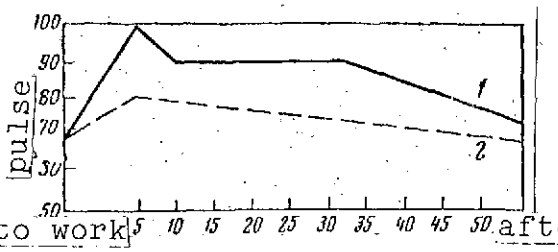


Figure 1. Pulse frequency during work on the EMO-3 device

1 — work with the emotiogenic stimulus; 2— work without the emotiogenic stimulus.

With the goal of determining the condition of the cardio-vascular system, arterial pressure was measured during and after work. Moreover, every five minutes of work the pulse frequency was recorded. Before and after work the electrocardiogram in three standard leads was recorded on the 2-channel "Elkar" type electrocardiograph. A total of two series of investigations was conducted with the participation of 22 subjects who ranged in age from 24 to 31 years. In the first series the subjects worked on the device for a period of fifty minutes without the application of the emotiogenic stimulus; during the second series of experiments the same subjects were given the emotiogenic stimulus on the EMO-3. Moreover, control measurements of the excretion of catecholamines were conducted in the state of calm.

As can be seen in Figure 1, during the first minutes of work with the emotiogenic stimulus, pulse frequency sharply increases (by 25-29 beats per minute), then somewhat falls, remaining at 20 beats per minute higher than the initial data, and at the end of work does not reach the initial values.

During intellectual work without the emotiogenic stimulus, we did not observe a high pulse frequency, and after work it fully returned to the initial level.

The subjects are divided into two groups according to the reaction of systolic pressure to intellectual activity with emotional stress. Systolic pressure increases from 114 $\pm$ 2.2 to 132.4 $\pm$ 2.3 /283

mm Hg in 68% of the subjects during work, and after work remains higher than the initial level. In 32% of the subjects, a tendency toward a gradual drop in arterial pressure is noted (113.3 $\pm$ 3 mm Hg before work, 108.4 $\pm$ 3 mm Hg after work). The reaction of the pulse to emotional stress was also lower in these subjects than in the remainder of the investigated persons. During work without the emotiogenic stimulus, no reliable changes in systolic pressure were detected (prior to work — 112.7 $\pm$ 1.26 mm Hg, during work — 115.3 $\pm$ 1.77 mm Hg, after work — 112 $\pm$ 1.48 mm Hg, $P>0.5$).

During work with the electrocutaneous stimulus, diastolic pressure increases by 11.1 mm Hg on the average (75.5 $\pm$ 1.5 mm Hg before work, 86.6 $\pm$ 1.5 mm Hg during work, $P<0.001$), and immediately after work remains higher than the initial level. It should be noted that an increase in diastolic pressure of 20-30 mm Hg was observed in 45% of the subjects.

During work without the emotiogenic stimulus, a statistically reliable increase in the diastolic pressure is also observed (74.7 $\pm$ 1.6 mm Hg before work, 81.3 $\pm$ 1.7 mm Hg during work, $P<0.001$). But this increase is nearly 2 times smaller than that which is observed during work under the effect of the emotiogenic factor. In the first minutes following the end of the experiment, diastolic pressure is higher than the initial figure by 4-5 mm Hg. Figures 2 and 3 show the data of measuring arterial pressure.

Here the presence of an inverse correlation relationship between pulse frequency, systolic and diastolic pressure during work and the value of their initial level should be noted (respectively, correlation coefficients of 0.250 $\pm$ 0.150; — 0.375 $\pm$ 0.130; — 0.414 $\pm$ 0.136).

During the analysis of the electrocardiograms, a reliable increase in amplitute of the P, R, and T spikes was found in 75% of the cases (the first and eleventh standard leads); after work with the emotiogenic factor, these were, on the average 0.2, 3, and 0.95mm respec-

tively. During work without the emotiogenic factor, no significant changes in the electrocardiographic indices were noted.

The data of the investigation of the rate of adrenalin excretion (in ng/min) are shown in Figure 4. As can be seen, the rate of adrenlin excretion during work under the effect of the emotiogenic stimulus increases by 70%, on the average: the rate of excretion prior to the experiment (over an interval of 1 and 1/2 hours) was 8.9 $\pm$ 0.7 ng/min; during work on the device it was 15.1 $\pm$ 1.1 ng/min, P<0.001. In 45% of the subjects, adrenalin excretion increased 2-3-fold. /284

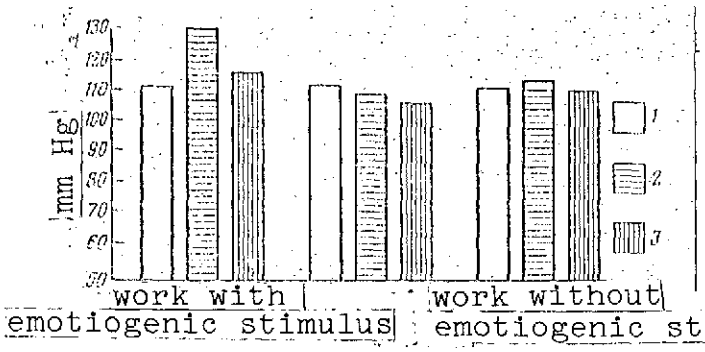
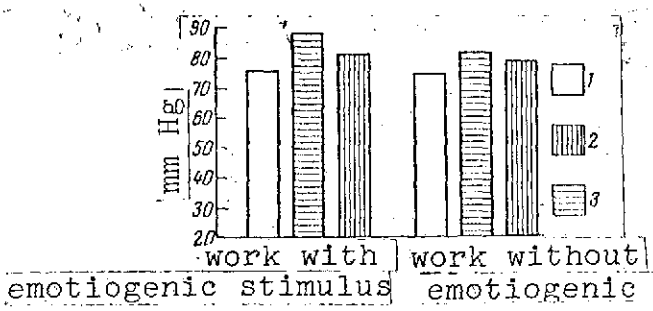


Figure 2. Systolic pressure during work on the EMO-3 device

1- prior to work; 2- after work; 3- during work.



1- prior to work;
2- after work;
3- during work.

Figure 3. Diastolic pressure during work on the EMO-3 device

During work without the emotiogenic factor, adrenalin excretion increases from 8.5 $\pm$ 0.73 to 11.2 ng/min. The increase in noradrenalin excretion is not proportional to the increase in excretion of adrenalin. The data shown in Figure 5 indicate that the per centage of adrenalin in the common total of excreted catecholamines increases from 24.1 to 30.5% in the case of work with the effect of emotiogenic

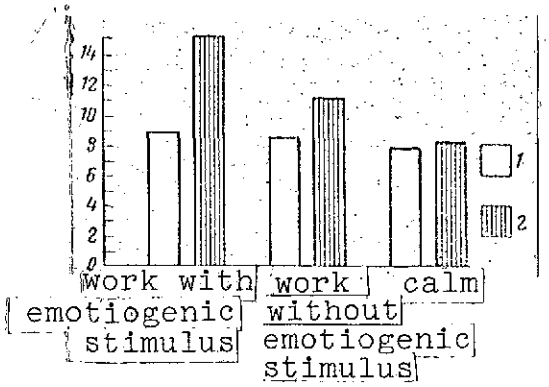


Figure 4. Excretion of adrenalin during work on the EMO-3 device

1- before experiment, 2- during experiment.

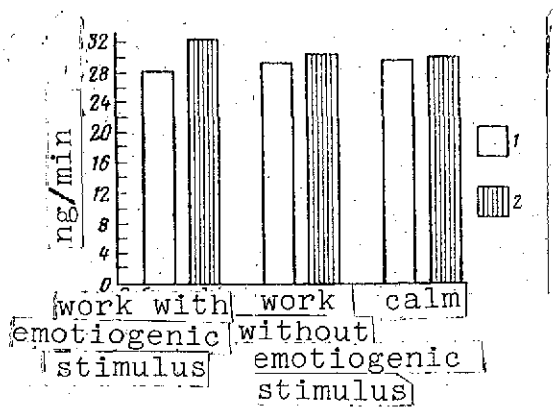


Figure 5. Excretion of noradrenalin during work on the EMO-3 device

1- before experiment, 2- during experiment.

factors, but during work without the emotiogenic factor, respectively, from 22.4 to 26.9%. The common total of excreted catecholamines during work with the emotiogenic stimulus increases by 10.5 ng/min; during work without it — by 3.6 ng/min. The increased output of catecholamines in the subjects is accompanied by the appearance of signs of external restlessness. A moderate degree of positive correlation relationship was found between the secretion of adrenalin and the pulse frequency and was statistically reliable ($r=0.56$; $P<0.001$).

Work with the emotiogenic factor was accompanied by an increase in the number of errors when solving problems provided for by the program of investigations (during work with an emotiogenic stimulus, the number of errors was 10 ± 0.88; without the emotiogenic stimulus — 6.5 ± 0.7). The subjects in whom work under the effect of the emotiogenic stressor was not accompanied by a significant change in the physiological indices solved the problem under the extremal conditions, just as under optimum conditions. Some of the subjects improved the quality of work with a significant physiological reaction to the emotiogenic factor, while others increased the number of errors in solving the problem. Table 1 shows the physiological indices and number of errors made in solving the problems on the part of the subjects during work on the EMO-3 device with and without the effect of the emotiogenic stimulus. In addition to an increase in the number of errors in solving the problems

/285

TABLE 1.

PHYSIOLOGICAL INDICES AND THE NUMBER OF ERRORS MADE WHEN SOLVING PROBLEMS ON THE PART OF INDIVIDUAL SUBJECTS WORKING ON THE EMO-3 DEVICE.

Subject	systolic pressure, mm Hg						diastolic pressure, mm Hg						excretion of adrenalin, ng/min				number of errors in solving problems	
	work with emotiogenic factor			work without emotiogenic factor			work with emotiogenic factor			work without emotiogenic factor			work with emotiogenic factor		work without emotiogenic factor		work with emotiogenic factor	work without emotiogenic factor
	before work	during work	after work	before work	during work	after work	before work	during work	after work	before work	during work	after work	before work	after work	before work	after work		
B-V	110	130	120	110	120	110	78	100	90	75	87	78	4,14	14,72	8	11	8	9
S-S	130	160	130	120	130	118	80	100	87	80	90	80	17,65	21,60	12,8	16,46	4	7
K-IY	120	140	120	128	120	130	80	90	83	83	90	90	10,18	26,65	12,6	12,5	12	1
M-IY	120	130	120	110	118	100	65	84	70	80	78	68	17,0	24,0	15,0	16,0	21	9
M-O	130	140	123	110	120	120	83	100	85	70	80	80	15,4	23,57	15,9	23,7	19	13
Ch-K	120	130	130	120	120	120	60	90	75	65	80	68	7,85	13,84	4,94	4,27	13	8
O-KO	100	100	90	110	110	110	60	70	73	60	68	68	19,60	15,60	10,0	6,0	5	5
G-KIY	110	109	93	100	100	108	78	70	70	68	68	70	12,70	10,45	12,1	13,5	9	8
Ch-Y	125	120	110	110	110	110	80	92	85	82	90	80	7,94	7,0	12,9	6,3	6	5

TABLE 2. THE EFFECT OF EMOTIOGENIC FACTORS ON SUBJECTS

Working regime on EMO-3	Time of differential reflex, μ sec.		Percentage of recalled figures	
	before work	after work	before work	after work
	M ± m	M ± m	M ± m	M ± m
Work under the effect of the emotiogenic factor	354±7,8	39,4±9 P<0,001	59,3±3,28	45,3±3,06 P<0,001
Work without the effect of the emotiogenic factor.	389±10,0	382±9,4 P<0,5	66,7±4,1	57,5±3,6 P<0,1

during work with emotional stress, a statistically reliable decrease in short-term memory and an increase in the time of differential oculo-motor reaction (Table 2) are noted. (The condition of the short-term memory was determined by recalling different geometrical figures presented to the subject before and after the experiment. The time of the differential reaction was determined by chronoreflexometry). /287

An analysis of the data provided in the table made it possible to conclude that after wrok with the emotiogenic stimulus the time of the differential reaction increases from 354 to 394μ sec on the average, i.e., by 40μ sec.

Work under optimum conditions does not significantly affect the time of the differential reaction.

Additionally, after work with the emotiogenic factor, the percentage of recalled figures decreases from 59.3 to 45.3%, i.e., by 14%. Work under optimum conditions decreases recall by 9.3%. /288

The results of our investigations indicate that the neuro-emotional component of intellecutal activity increases the functional activity of the sympathico-adrenal system and that during the process it acts differentially on the adrenomedullary and mediator regions. This is possibly caused by the varying physiological role performed by the catecholamines in the body and by the exis-

tence of different centers for regulating their secretion. Adrenalin is a hormone that is rapidly mobilized in "critical situations" that threaten the disruption of the body's homeostasis, while noradrenalin is a mediator of the sympathetic nervous system that acts more locally; it is secreted at an acceleratedcpace during pronounced physiological changes in the body. The oppositely directed changes in the secretion of adrenalin and noradrenalin observed in the subjects in a number of cases can be viewed based on the data of special investigations performed by A.M. Baru as centrally-caused dissociation of the adrenomedullary and peripheral noradrenergic activity and as "a result of the fact that the formation of the emergency-adaptive reactions can be accompanied by a decrease in the activity of homeostatic mechanisms under certain conditions." Euler [26] thinks it is possible to estimate the degree of emotional stress according to the value of changes in the excretion of catecholamines.

Our data also indicate a significant effect of neuro-emotional stresses on the functional condition of the myocardium and on the hemodynamics during intellectual work; it should be noted that the increased level of arterial pressure and pulse frequency are maintained only during the accomplishment of stressful work, and immediately after the conclusion of such work these indices rapidly return to normal, due to the powerful homeostatic mechanisms; in the absence of a capacity to regulate these indices in the subjects, it would be very difficult to detect these changes in absolute values during stress. Arousal of the adrenergic substrate and the effect of secreted adrenalin and noradrenalin play an important role in changing the condition of the cardio-vascular system during emotionally stressful intellectual activity. Both catecholamines increase the rate of cardiac contraction and increase the strength of contractions. But during this process, adrenalin has greater effect than noradrenalin, which could be due to the stronger metabolic effect of adrenalin on the myocardium. In stimulating the cardia activity, both catecholamines increase the systolic pressure. They have an evenly-directed effect on the diastolic pressure. Adrenalin, in lowering the peripheral resistance of the blood vessels, thereby enables a decrease in pressure, while noradrenalin,

in increasing the peripheral resistance of the blood vessels, increases the diostolic pressure. In causing an increase in both systolic and diastolic pressure, noradrenalin increases mean arterial pressure, while within physiological limits adrenalin evokes very slight changes in the mean arterial pressure. The characteristics of the effect of catecholamines on the hemodynamics depend on their dosage to a great extent. Thus, in small amounts adrenalin and noradrenalin do not cause significant changes in the arterial pressure, but are clearly revealed in the cardio-vascular reactions.

The correlation relationships we established between the degree /289
of increase and excretion of adrenalin and the increase in pulse frequency and systolic pressure under high neuroemotional stress, as well as the mathematical analysis of the cardia rhythm confirm the hypothesis that a significant increase in emotional stress of the functional activity of the sympathico-adrenal system can differently affect the reliability and effectiveness of operator work.

There is reason to hypothesize that the effect of adrenalin on the higher nervous activity is determined to a known degree by the typological characteristics of the higher nervous activity. Thus, although strengthening the arousal process in the cerebral cortex of dogs of the strong type with an adequate threshold of functional capacity of the cortical cells, adrenalin causes the development of a post-threshold inhibition in dogs of the weak type. The detected relationship of the degree of change of the studied indices on their initial level intermingles with the data of a number of other authors. Thus, Plutchik [27], in an analysis of individual differences in the organisms reaction to emotional stress, and M.R. Mogendovich [28], in studying the human vegetative reactions to the effect of the most varied stimuli showed that the higher the initial level of vegetative tone of a given function, the less the change evoked by the stimulus, i.e., the lower reflexive excitability will be. According to the data of Wilder [29], with an extremely low or an extremely high initial level of excretion of noradrenalin, the response is either absent or a paradoxical reaction is noted.

Hence, the working capacity of the operator under conditions of the effect of emotiogenic factors to a great extent depends on the individual functional characteristics of the cardio-vascular and sympathico-adrenal systems.

Additionally, it should be recognized that a decisive factor in human occupational suitability for effective and reliable accomplishment of operator functions in different working regimes is his moral, intellectual, will-power, emotional, and other personality qualities.

REFERENCES

1. Orbeli, L.A. Lektsii po fiziologii nervnoy sistemy (Lectures on the Physiology of the Nervous System) Leningrad, 1938.

2. Kennon, V. Fiziologiya emotsiy. (The Physiology of Emotions) Leningrad, 1925.

3. Sel'ye, G. Ocherki ob adaptatsionnom sindrome. (Aspects of the Adaptation Syndrome) Moscow, 1960.

4. Gel'gorn, E. G. Lufborrow. Emotsii i emotsional'nyye rasstroystva. (Emotions and Emotional Disorders) Moscow, 1966.

5. Elmadjan, F. I.M. Hope, and E.T. Lamson. Excretion of epinenhrine and noreninepnrine under stress. "Recent. Progr. Hormone Res.", Vol. 14, New York-London, 1958.

6. Anokhin, P.K. Emotional Stress as a Forerunner to the Development of the Neurogenic Diseases of the Cardio-Vascular System. "Vestnik akademii med. nauk SSSR", No. 6, 1965.

7. Simonov, P.V. Teoriya otrazheniya i tsikhofiziologiya emotsiy. (The Theory of Reflection and the Psychophysiology of Emotions) Moscow, 1970.

8. Makarenko, Yu.A., Characteristics of the Central Mechanisms of Vegetative Reactions During Autostimulation. Sistemnaya organizatsiya fiziologicheskikh funktsiy. (Systemic organization of the physiological function) Moscow, 1969.

9. Mikhaylova, N.G. The Emotion-Positive Arousal during the Reaction of Autostimulation. The Structural, Functional, and Neurochemical Organization of Emotions. Materialy vsesoyuznogo simpoziuma. (Materials of an All-Union Symposium) Leningrad, 1971.

10. Lang, G.F. Gipertonicheskaya bloezn'. (Hypertonic Disease) Leningrad, 1950.

11. Myasnikov, A.L. Gipertonicheskaya bolezn'. (Hypertonic Disease.) Leningrad, 1960.

12. Polishchuk, I.A. and P.V. Biryukovich. Characteristics of the Pathogenic Effect of Intellectual Overstress and Overfatigue. Fiziologicheskaya Kharakteristika umstvennogo i tvorcheskogo truda [Materialy simpoziuma] (A Physiological Characterization of Intellectual and Creative Work [Materials of a Symposium]) Moscow, 1969, p. 101.

13. Vashetko, V.N. and L.Ye. Koroleva. The Role of Intellecutal Overstress in the Provocation of Endogenic Psychoses. Fiziologicheskaya kharakteristika umstvennogo i tvorcheskogo truga [materialy simpoziuma] (A Physiological Characterization of Intellectual and Creative Work [Material of a Symposium]), p. 23.

14. Anokhin, P.K. Emotsii. (The Emotions) BME, Second Edition, 1964, p. 35.

15. Pekkarinen, A., O. Castren, and O. Lisalo. The emotional effect of matriculation examination on the excretion of adrenalin, noradrenalin , 17-hydroxycorticosteroids in the plasma. Biochemistry pharmacology and physiology. New York, 1961, Pergamon Press, Lus. pp. 117-137.

16. Grishko, F.I. and A.N. Ratushmaya. Age Characteristics of the Reaction of the Sympathico-Adrenal and Hemodynamic Systems to Stressful Intellectual Work. Materialy nauch konf, po vozrast. morfolog., fiziolog. i biokhim. (Materials of a Scientific Conference on Maturational Morphology, Physiology, and Biochemistry) Moscow, Vol. 2, Part 1, 1969, p. 196.

17. Dlusskaya, I.G., I.D. Malinin, and I.S. Balakhovskiy. A Comparison of the Excretion of Adrenalin and 17 Oxycorticosteroids with an Estimate of Working Capacity of Operators under Conditions of a Long-term Experiment. In the collection: "Fiziologiya i biokhimiya biogennykh aminov" (Physiology and Biochemistry of Biogenic Amines) Moscow, 1969.

18. Frankenhaeser, M. and B. Post. Catecholamine Excretion during Mental Work as Modified by Centrally Acting Drugs. Acta physiol. Scand, 1962, p. 55.

19. Grivel, F., G. Witters, V. Scheim, V. Baumsttemler, and Metzb. Analyse experimentale de la deberioration des performances sous l'infuluen ce de trois facteurs de batique. (An Experimental Analysis of Performance Deterioration under the Influence of Three Fatigue Factors) "Arch. malad probess.", Vol. 22, No. 8-9, 1961.

20. Patkai, Catecholamine Excretion and Performance. "Forsvars-medicin", Vol. 3, No. 2, 1967.

21. Juichi, K., A. Kozima, and V. Niiyma. Cardiac rhythm and Adrenaline Excretion Physiological Parameters for Mental Stress for the Study of Work Physiology. "Indus. Health', Vol. 3, No. 1-2, 1965.

22. Euler, U.S. Quantitation of Stress by Catecholamine Analysis. Clein. Pharmacol. and Therap., Vol. 5, No. 4, 1964.

23. Lowi, L. New Stress Tolerance Test with Simultaneous Study of Physiological and Psychological Variables. A Preliminary Study. Acta endocrinal, 1961, Vol. 37, No. 1.

24. Podoba, Ye.V. Serdechno-sosudistaya sistema i nervno-napryazhennyy trud. fiziologicheskaya kharakteristika umstvennogo i tvorcheskogo truda [Materialy simpozimua] (The Cardio-Vascular System and Neuro-Stressful Work. A Physiological Characterization of Intellectual and Creative Work [Materials of a Symposium]), p. 97.

25. Psikhologicheskiy otbor letchikov (Psychological Collection of Lectures) Edited by Ye. A. Mileryan. Kiev, 1966.

26. Euler, U.S. Quantitation of stress by Catcholamine Analysis. Clein, Pharmacol. and Therap., 1964, Vol. 5, No. 4.

27. Plutchik, R. Psychophysiology of Individual Differences with Special Reference to Emotions. Ann No.5, Acad. Sciences, 1966, No. 2, p. 134.

28. Mogendovich, M.R. The Question of the Type of Human Vegetative Reactions "Materialy VI Ural'skoy knoferentsii fiziologov, farmakologov i biokhimikov v g. Tyumeni" (Materials of the Sixth Ural Conference of Physiologists, Pharmacologists, and Biochemists Held in Tyumen). Sverdlovsk, 1969.

29. Wilder, I. Adrenaline and the Law of Initial Value. A Critical Survey.Exptl. Med. and Surg., Vol. 15, No. 1, 1957.

N75 17958

THE PSYCHOLOGICAL CERTIFICATE OF THE COMPUTER

Ye.A. Mileryan*

The effectiveness, reliability and quality of work of the specialist employed in modern industry to a great extent depend on the degree of correspondence of the working conditions and demands made by controlling new technology and his capacities, psychological qualities, interests, requirements, and personality qualities.

A study of the psychological characteristics of work under conditions of modern scientific-technical progress has clearly shown that modern work not only makes increased demands on the professional, polytechnical training of the worker, but also requires the appropriate development of the intellectual, emotional-will, and particularly, the moral spheres of his personality. Additionally, the design of technical systems frequently is carried out without considering human capacities. Therefore, the use of new and complex technology in certain situations does not produce the expected effect, but sometimes leads to extreme neuro-psychological stresses, occupational diseases, accidents, emergencies, and other undesirable consequences. With respect to this, the design of such "man-machine-industrial environment" systems in which optimum conditions would be created for human work, and which would make work creative, healthy, pleasant, highly productive, well-organized, and a highly effective source of comprehensive development and communist education of the new man emerge as the primary task of investigations in the field of occupational and engineering psychology. In this way, psychology makes its contribution to solving one of the primary problems of communist building formulated at the Congress of the Communist Party of the Soviet Union. This is why the general trend in modern investigations in the fields of labor and engineering psychology is humanization of scientific-technical progress.

/290

/291

*Kiev, Institute of Psychology of the UkSSR.

Psychological investigations have demonstrated the presence of two basic ways of solving this problem. The first of these is through psychological selection, training and education of people most capable of mastering any particular occupation. The second way is by optimizing the conditions of labor and consists in creating the most favorable, business-like and friendly relationships in the working collective, in efficient coordination and distribution of functions between man and machine, and finally, in the development of more improved forms of organizing labor and its technical means with respect to man (control panels, machines, machine tools, equipment of working areas, instruments, etc.) whose use ameliorates human work, making it creative, pleasant, non-fatiguing, healthy, and highly productive.

A vital condition for solving all these problems is creating a combined method of engineering-psychological measurement and estimates of the quality of technical systems with respect to the average capacities of the people controlling them.

With respect to this, it should be noted that in recent years in our country, a new scientific trend has arisen and is successfully developing — qualimetry — that is concerned with the development of general principles and methods of quantitatively measuring and estimating the quality of products, processes, and forms of organizing labor. Within the range of problems solved by this science is also the creation of methods of tariff-qualification evaluation of the level of professional skill or quality of specialists engaged in the most varied branches of general industry. It is natural to assume that the solution of qualimetric problems has an important role for occupational and engineering psychology.

The newspaper, "Pravda" accepted and supported the initiative of Ukrainian psychologists who indicated the need for "having each product have a psychological certificate in addition to its technical specifications" [1]. However, for compiling such a certificate a special method was required by whose aid it would be possible to carry out an objective psychological estimate of the quality of

equipment, and the personal capacities of the people controlling it.

The main difficulty consisted in creating an engineering-psychological theory from which it would be possible to develop a unitary system of objective criteria and scales of estimates of the conditions and requirements made on the specialist by working in a given systems-technical complex. It is known that each somewhat /292
complex industrial product is obligatorily provided with a technical specification which reflects its basic parameters, properties, and technical and economical characteristics that in toto characterize the operating properties of the given product, besides bearing a general estimate of quality. Thus, the technical specifications of a radio receiver contain data on its sensitivity category, selectivity, range of operation, power requirement, etc. The technical specifications of a metal-working machine tool can give information on its class, the number and nature of operations it accomplishes, the permissible speed of cutting, the expenditure of electricity, the main operating regimes, insturctions on the rules of care and operation, etc.

Additionally, there is a widely-accepted tariff-qualification system of norms on whose basis the level of worker qualification is determined. Thus, workers employed in industry are given categories; operators, pilots, drivers of vehicles, locomotives, busses, metro trains, and other transport facilities are awarded classes; engineering-technical workers are awarded categories, etc. In essence, one is dealing here with an estimate of the quality of the worker, of his capacity to accomplish certain complex assignments related to using a certain quality of equipment, technology, and organization of /293
industry. The more complex and responsible the work, the higher must be the qualification fo the person performing it. This is the basic empirical rule of the distribution of functions in modern industry, transport, construction, agriculture, or military affairs. Thus, piloting aircraft on long distance and complex flights is a job entrusted only to first class pilots, while highly accurate, responsible and complex welding, cutting, and other such operations are carried out by highly-qualified workers using high-class, accurate

machine tools. Additionally, existing systems of estimating machine qualities are in inadequate agreement and sometimes contradict the tariff-qualification manuals, regulations, instructions and other official documents by whose aid the level of qualification of specialists is determined. Thus, for example, our existing practice of awarding classes to vehicle drivers is characterized by the fact that in order to obtain the highest rating — first class driver — an examination on the construction and operation of vehicles of the newest types must be passed, as well as an examination on the capacities to repair, adjust, assemble and regulate vehicles having internal combustion and deisel engines. Hence, the main criterion for acquiring the first class is a knowledge of the equipment, rules of its operation and repair. In this method of estimating the level of qualification, the most important aspect is left from view, namely, mastery of vehicle driving under complex, extreme conditions, whose level primarily depends on emotional stability, self-control, quickness of wits, initiative, discipline, no inclination for risk, rapidity of reactions, and other personality qualities of the driver.

Moreover, in a number of the norm documents, there is a serious lag behind the rapidly growing requirements of the newest equipment. Therefore, for example, the welder or metal cutter having a high class rating cannot always successfully operate the new equipment.

Hence, vast scientific-technical progress in all fields of industrial production, construction, transport, energetics, agriculture and military technology have advanced to the fore of the problem of estimating the quality and reliability of work of those specialists accomplishing service functions, programming, control, installation and regulation of complex automatic assembly lines, machine tools, aggregates, machinery, and other technical systems.

Further advance in this field relates to developing objective methods of engineering-psychological expertise in the quality of system-technical combinations with respect to the capacities of the people controlling them.

In this regard, it seems promising to us to make the systems-structural, all-regime approach to studying the work of the specialist, which is inseparably linked with discovering the general structure of this activity in order to clarify objective and subjective conditions, and to determine the reliability and effectiveness of the operator's accomplishment of specific structural functions and all structural functions entrusted him.

The investigation of occupational structures should not only clarify their components, but also reveal the functional relationships existing between them. This is all necessary so that we will be able to go from the isolated study of labor functions prevalent today to the integral structural investigation of the reliability and effectiveness of their accomplishment as a component of any particular activity.

The psychological study of operator occupations shows that each /294
of them makes its own specific demands on man. Additionally, the occupational activities of operators controlling the most varied systems are in many ways similar in their psychological structure. This provides a basis to note a common structure of activity that consists of the following basic interrelated functions for all the variations of this occupation.

Its initial element is the function of active, goal-directed observation, in the course of which perception, selection, analysis and decoding of incoming information occur, and in which an adequate concept of the condition and tendencies of further development of the processes controlled by the operator is created.

The capacity to observe, actively follow, analyze and summarize data characterizing the course of the controlled processes and to take into account the tendencies in their development is a necessary component of the activity of operators of any kind.

The next element in operator activity is characterized by organization of information obtained in the process of observation in an

integral system of interrelated characteristics, as the result of which a whole clearly differentiated image or model of the situation is synthesized and orientation in the created situation occurs; the conditions of the problem arising before the operator are then clarified and formulated.

The next stage in this activity is usually linked with the appearance of a plan for solving the problem assignment. In thinking, analyzing, and clarifying the conditions of the problem that has appeared before him, the operator strives to formulate a certain approach to solving the problem, and in realizing his intent, to find an optimum program for using the means and methods of its solution that he has at his disposal.

Practical operator thinking is the leading element in solving problem assignments.

The next basic function of the structure we are examining is characterized by making a decision concerning the strategy of conduct, and by specific planning of an action to be applied to the controlled system, expressed in intellectual conceptualization of the temporal and spatial sequence of accomplishing all actions that ensure achievement of the set goal. This stage is characterized by the development of strategy and the operational plan of action.

An important sturctural element of the examined activity is the practical sensory-motor actions directly regulating and controlling the technical system. These actions are a motor realization of the earlier-developed program of regulation and control. /295

In this branch of operator activity, a leading role belongs to the sensory-motor capacities and skills that are usually used in controlling the given systems. Here, speed, accuracy, coordination of movements and harmony of actions carried out in accordance with the earlier-developed program emerge in first place.

The leading element of operator activity is controlling and

estimating the accomplishment of planned operations; at this stage a lack of correspondence between the results and the goal of activity is revealed and corrected. Based on the general structure of operator activity described above, we have been able to obtain certain psychological criteria for estimating the quality of accomplishing functions in different regimes and conditions of labor that enter the structure.

A psychological study of operator work makes it possible to pinpoint the educational-training minimum, optimum, and extreme regimes of operator work,

The educational-training regime has as its goal the formation, reinforcement and improvement of occupational knowledge, skills and capacities employed in the given type of operator activity. The program of training is usually strictly planned anc carried out using special simulators or the actual working objects, under the supervision and control of an instructor who is fully responsible for the reliability and effectiveness of his students' work.

The minimum regime of operator work usually exists during the control of a normally operating, highly automated system. The characteristic hallmark of this regime is the following: underload of useful information, the absence of a need to control and the effect of monotony, which often leads to loss of alertness, and causes human transition from the state of "operational calm" to the hypnotic state, as the result of which breakage of the pathways between the sensory perception of the situation and its conceptualization occurs. The development of hypnotic states is accompanied by significant delays in decision making and in accomplishing actions in response to emergency signals, which naturally creates the prerequisites for the appearance of breakdowns, emergencies and accidents. Operator work in the minimum regime is accompanied by the danger of partial or complete failure to accomplish the functions entrusted to him.

The accomplishment of operator functions in the optimum regime is carried out under comfortable conditions. Here, there is usually

Y296

normal operation of the automatic devices. The operator must merely follow the on-going condition of the system he controls, making corrections and regulating those of its parameters in which a tendency toward exceeding the limits of the norm is detected. The situation is familiar and actions are mainly carried out automatically at the level of habits at the voluntary tempo. Stereotype operator accomplishment of working actions occurs in a strictly determined order, and his thinking has an algorithmic character. A main role in activity of this type is played by skills acquired earlier by the operator that function with his attention concentrated.

Control of modern equipment under extreme conditions of work sharply increases demands made on the intellectual, and particularly, the emotional and will-power spheres of human personality. Work in complex, important and unexpected siutations requires the presence in the operator of a highly developed sense of self-control, the ability not to succumb to the effect of the most varied objective and subjective stress factors and the cpaacity rapidly to analyze the on-going condition of the system being controlled, in order to determine the causes of failure in its operation, the capacity in the shortest possible time to find ways to eliminate malfunctions, to make decisions in a timely fashion and reliably, without fluctuations and delays in adequately realizing the decision by the aid of a certain system of working actions, and finally, to control the effectiveness of measures taken in a qualified fashion. In this working regime, general-technical capacities expressed in the capability of the worker successfully to achieve a consciously developed new (for the worker) chain of labor activity by means of creative application of general means and methods of accomplishing work emerge foremost. Being the automatic components of skills, habits continue to play an important role that is, however, subordinate to capacities.

Besides discomfort and severe limitation in time, normal accomplishment of all operator functions under the conditions of stress is complicated by a sense of responsibility that appears as the result of recognition that errors, delays, ommissions and breakdowns

caused by the operator can result in accidents, catastrophies, and other undesirable consequences. There is also a qualitative change in the content and character of operator thinking. Thus, if in the optimum regime he could use ready, stereotyped solutions, then in the continuously changing, frequently unexpected and new situations of stress, the heuristic components of thinking, related to non-stereotyped behavior and creative application of knowledge and skills for practical purposes primarily emerge. /297

Resourcefulness, quickness of wit, endurance, resistance under fire, bravery, stability and a highly developed sense of duty and responsibility for actions are the personality qualities upon which the success and effectiveness of specialists controlling any technical system depend.

The above indicates that the extreme regime of work makes very high demands on the personality. The satisfaction of these demands is not within the scope of everyone having the necessary professional knowledge, capacities and skills and who successfully accomplishes operator functions in the training, minimum, and optimum working regimes. This is why psychological diagnosis of the reliability and qualities of the operator should show the interrelationship and determine the degree of effect of the professionally important capacities and personality qualities on working capacity and the behavior of the operator under stressful working conditions. The general estimate of the quality of the operator's work can be carried out by means of summarizing the estimates derived according to each of its properties. There is also another more promising possibility for constructing a scale of non-dimensional estimates oriented towards the basic structural elements of operator activity. In this case, the common estimate of the quality of work can be carried out by means of information according to certain formulas of estimates in points characterizing the quality of accomplishing individual functions in different working regimes. From this point, it becomes possible quantitatively to measure qualities by means of calculating the relationships if indices of productivity in the optimum and extreme working regimes. The formulas for determining these indices

can be obtained in various ways, and for each element of the structure of operator activity, there are unique indices of working quality. Thus, for example, the reliability and quality of functioning of the sensory-motor structural element can be measured by calculating the so-called coefficient of control, which is the product of the ratio of the total time of error-free actions to the total time of accomplishing a program. The percentage relationship of erroneous and correctly accomplished operations, etc. can be an index of the effectiveness of the intellectual functions.

It is natural to assume that the success of estimating the /298
quality of operator's accomplishment of his functions primarily depends on the degree of adequacy of the criteria chosen by the investigator, and secondly, on to what extent the conditions of the experiment ensure the capacity objectively to measure the parameters of quality under optimum working conditions and those changes that appear in the extreme working regimes; third, to what extent the requirements necessary for obtaining statistically reliable data are observed. The latter can be obtained under conditions of participation of an adequate number of subjects whose activity is positively motivated and carried out in the regimes simulating actual working conditions in the experiments.

As the result of a critical analysis and summarization of Soviet and foreign experiments, we have developed a new method for engineering-psychological estimation of the quality of systems-technical complexes. This method was constructed on the basis of considering all of the requirements ennumerated above. For clarification of the essence of our approach, one can refer to the method of estimating reliability and effectiveness of operator accomplishment of the sensory-motor control functions.

The given method was realized by the aid of the emocoordinometer, which provided automatic programming of the course of experiments and objective recording of the results of subject activity (see pp. 51 - 53).

The essence of tests on the emocoordinometer consists of manipulating the appropriate levers and pedals of the apparatus so as to bring the viewer into alignment with an assigned curvolinear line. The movement of the viewer in the plane of the screen is carried out by means of an electric motor, the speed and direction of the viewer along the vertical are determined by the angle of inclination of the lever, while its speed and direction on the horizontal are determined by the position of the control pedal. Mediated by the operation electrical motors, the control of viewer movement required quite accurate and fine coordination.

The character of activity of the subjects schematically simulated the structure of the sensory-motor actions of aircraft control.

The investigation consisted of 3 series of experiments. In the 1st — the educational-training series — the subjects learned to operate the given apparatus; in the 2nd series, optimum conditions for accomplishing the sensory-motor functions assigned the subjects were created; in the 3rd series these functions were carried out in the extreme working regime.

The level of reliability of control was determined by means of comparing the indices characterizing the effectiveness of accomplishing the sensory-motor functions under extreme conditions with respect to the same indices in the optimum working regime. Having divided the time over the course of which the viewer was located within the limits of the band of the programmed line by the time spent on accomplishing the program, we obtained the coefficient of control "r".

By correlating the mean values of the control coefficients obtained under the optimum and extreme conditions of the experiment, we were able to draw conclusions on three changes in the reliability and effectiveness of activity that appeared as the result of the effect of stress factors. In the capacity of the latter, we first used painful electric shocks that automatically af-

fected the subjects with each movement of the viewer beyond the limits of the programmed line, and 2nd, acute limitation of the time allowed for accomplishing the assignments, using the moving slide. In the case of untimely actions of the subject, the slide closed off the line and thereby threatened complete disruption of accomplishing the assignment.

By the aid of the emocoordinometer described above, we conducted three series of experimental investigations in which 198 candidates for admission to one of the Higher Aviation Academies of the Soviet Air Force participated, (a total of 198 subjects in all three series). All subjects were interested in obtaining the best results during the experiments on the apparatus, since their acceptance to the school depended on these results.

The basic index characterizing success in the subjects' accomplishment of their assignments was the coefficient of control, which was calculated according to the formula shown below by means of dividing the time during which the viewer was located within limits of the curvolinear line band by the total time spend on control:

$$r = \frac{t}{T}$$

where r-coefficient of control, t-time viewer stayed on the line, T-total time spent on accomplishing the program.

Conclusions were drawn on the basis of compiling mean values of the coefficient of control r_o obtained under optimum conditions with the mean coefficient of control r_e characterizing the extreme working regime. Naturally, during this process behavioral characteristics of the subjects during the experiments were also considered. The primary index of the quality of accomplishing the sensory-motor function of control was the coefficient of working capacity R, which was calculated according to the formula, /300

$$R = r_e - r_o.$$

Analysis and summarization of the obtained experimental data and the construction of a distribution curve of variants (Figure 1)

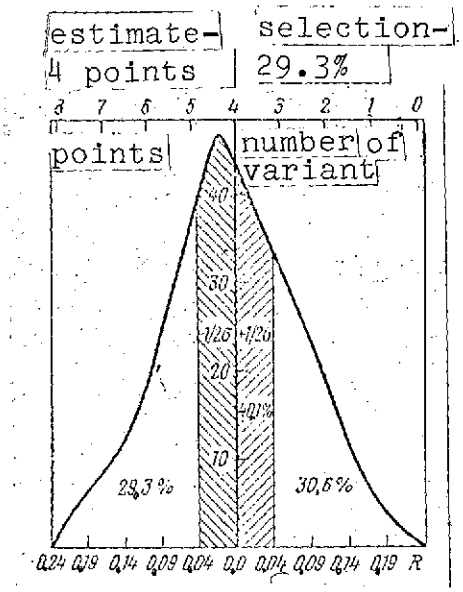


Figure 1. Estimating the class of a system according to the level of reliability of operator accomplishment of sensory-motor control functions.

made it possible to divide our subjects into 3 basic groups. The 1st group included those subjects (40.1%) in whom working capacity during the transition from the optimum to the extreme working regime did not undergo significant changes, while the difference between the mean values of the coefficients of working capacity were near zero and were within limits of $\pm$ 1/2σ.)

In subjects of the second group (29.3%), there was a sharp decrease in working capacity up to the point of complete disruption in accomplishment of the assignments during exposure to stress factors; in this case, the values of R had a negative sign, and according to absolute value were less than 1/2σ.

The third group (30.6%) of the people who participated in the experiment were distinguished by a progressive increase in their working capacity under conditions of stress. Here, the values of R always had a positive sign, and with respect to their absolute value exceeded 1/2σ.

In ranking the obtained values in the order of increment of values, i.e., in placing the subject who had the worst results, R= -0.24, at the bottom of the table, in 198th place, and in putting the best results, R=+0.24 in first place, we divided the obtained rank table into eight octaves. During this process, the boundaries of the octaves were determined by the following value percentiles: /301

Octaves	Percentile rank index	Octaves	Percentile rank index
I	0—12,5%	V	50—62,5%
II	12,5—25%	VI	62,5—75%
III	25—37,5%	VII	75—87,5%
IV	37,5—50%	VIII	87,5—100%

Having divided the table of ranks into octaves, we obtained the following 8-point scale of estimates of the quality of sensory-motor control functions accomplished by our subjects in the extreme working regime.

The scale of estimates of the quality of accomplishing sensory-motor functions

values of R	points	values of R	points
0,18 and higher	8	0 to −0,4	4
0,17 to 0,11	7	−0,5 to −0,10	3
0,10 to 0,5	6	−0,11 to −0,17	2
0,4 to 0	5	−0,18 and lower	1

Using the scale shown above, we were able to provide a point estimate of the level of qualification of each subject depending on value R. Naturally, such an estimate pertained only to accomplishing the sensory-motor element of the activity structure of the operator. Additionally, in order to obtain a comprehensive general structural estimate, it was necessary to obtain a scale of estimates of the accomplishment of functions with respect to all of the remaining structural elements by means of specially organized experiments. In this case, one could use the formula cited below for the weighted mean arithmetical estimate in points, set up according to each of the structural elements for the comprehensive estimate of the level of qualification or class of the operator:

$$W_{op} = \frac{K_1 V_1^0 + K_2 V_2^0 + K_3 V_3^0 + \ldots + K_j V_j^0}{n_j},$$

where W_{op}-total estimate of operator class in points; K_1, K_2 ...,K_j -weight of basic structural functions, ...V_1^0, V_2^0, ...V_j^0 — estimate in points of the effectiveness of operator accomplishment of each of the basic functions; n-number of functions. /302

It is natural to assume that the practical application of the formula given above requires determining the specific importance of each of the structural elements in the total structure of operator activity, in addition to determining the scale of estimates for each of the structural elements. It is obvious that these weights could have different significance depending on the degree

of influence of the operator's accomplishing each function on the final result of a specifically chosen occupational activity. In those cases when the operator accomplishes only part of the functions of a total structure, such an estimate can be made according to an abbreviated formula.

Subsequent progress in solving the problem we investigated is inseparably linked with developing methods of determining the class of a technical system with respect to the average capacities of the operator controlling it. In this case, if one succeeds in using the same scale of estimates to determine the class of the technical system and the operator, then we are approaching a clarification of the conditions under which optimum correspondence of individual qualities of the specialist and the demands of the equipment he services is ensured. With this goal, it is mainly necessary to resort to cruder analysis and theoretical summarization of the experimental data obtained. Thus, in examining the curve of distribution of the variants shown in Figure 1, we can find an extremely interesting point with the coordinate "0" along the axis of the abscissa, without difficulty. The ordinate placed in this point divides the polygon of the distribution curve into a region of positive values of index R, which includes all subjects who effectively carried out the sensory-motor functions related to controlling the given system, and the negative values of R, where that portion of the people whose effectiveness diminished with respect to accomplishing the same function at the transition to extreme working regime is concentrated.

Hence, the ordinate of point 0 is the boundary that separates the mass of operators working at different levels of effectiveness. Taking this fact into account, we can revert to constructing the eight-point scale of estimating the class of a given system with respect to the average capacities of the people working on the system. Such scales can be non-uniform or uniform. In order to construct uniform scales of class estimates of the system, it is necessary to divide the entire range of R variations into 8 classes with an even class interval.

Graphically, the eight-point scale of estimates can be given in the form of a segment directly parallel to the axis of the abscissa and divided into 8 uniform regions limited by perpendicular lines made up of points characterizing the extreme values of the variants. Having carried out the operation of combining the scales of estimates with the distribution curves of variants characterizing the effectiveness of our subjects' accomplishment of operator functions, we thereby obtained the capacity to estimate the class of the technical system in which the experiments were conducted. For this purpose it is necessary to extend the ordinate of point 0 to its intersection with the nomograma of the eight-point scale of estimates. In our case, the aircraft control system used in the emocoordinometer receives a rating of nearly 4 points. /303

Construction of the non-linear eight point nomograms of estimates can be carried out by means of projecting the abscissas and ordinates dividing the polygon of the normal curve of distribution into eight parts equal in area onto a plane-parallel axis. The non-uniform scale of estimates bbtained in this fashion is more accurate in comparison with the uniform one, although its practical use presently entails a number of difficulties of a technical nature. However, there is every reason to assume that in the process of further development of the mathematical apparatus, these difficulties will be resolved and an extensive capacity for employing non-uniform scales for practical goals will be obtained.

By analogy with the material presented above pertinent to the method of determining operator class, the class of the technical system can be calculated according to the formula

$$W_s = \frac{K_1 V_1^s + K_2 V_2^s + K_3 V_3^s + \ldots + K_j V_j^s}{n_j},$$

where W_s —general estimate of the class of the technical system, in points; K_1, K_2 ..., K_3 —weight of basic operator functions; V_1^s, V_2^s, ..., V_j^s —estimate of the quality of the basic structural elements of the technical system, in points, pertinent to the average capacities of the operator.

Using the method described above, one can obtain all the parameters that enter the formula for system quality. For this purpose, it is necessary to construct distribution curves of the indices characterizing the level of accomplishing each of the basic functions, to determine their specific importance and to estimate them according to the eight-point system using experiments conducted with the participation of an adequately large number of operators. Consequently, when estimating the quality of similar systems, one can /304
limit oneself to the participation of a small number operators whose class has been determined earlier. It is not impossible to use this basis to develop general criteria and scales of estimates that can be employed at the stage of planning new technical systems similar to the existing ones.

The estimate characterizing the class of a system with respect to the averaged capacities of the mass of people tested on it simultaneously orients us with respect to the norms of weeding-out inadequately reliable operators. Thus, if one adds the operators in whom slight negative changes were observed under the extreme conditions to the number reliable operators, such changes not exceeding $(-1/2\sigma)$, then the ordinate set accordingly (-0.04) will divide the polygon of the curve (see Figure 1) into the region of "reliables" (70.7%), and the region of "unreliables" (29.3%).

From here it is not difficult to draw the following conclusions. During psychological selection of operators for the technical system of a given, i.e., 4th class, the norm of weed-out should comprise 29-30%, while the pass point should be no lower than 4 (see the scale of estimates of reliability of accomplishing sensory-motor functions).

It is natural to assume that with the increase in class of the technical system, the demands it makes on the operator should decrease and the weed-out norms should decrease. One of the experimental indications of the truth of this assertion is found in the material of an investigation we made in which the effectiveness of work of 89 subjects was checked on the emocoordinometer with improved control elements and increased reactiveness of the con-

trolled object.

Having constructed a distribution curve of the obtained experimental data, and having carried out all operations necessary to determine system class (Figure 2), we concluded that the result of improving the design was that the class of our technical system increased by 1 point and became 5.1, while the weed-out norm decreased to 20.2% and the pass point or class of operators capable of working reliably according to the given system also decreased to 3 points.

Therefore, one can consider proven the existence of a determinable relationship between the class of the system and the class of the operator serving it: the higher the class of the system, the lower the demands made on the operator by it, and consequently, the larger the number of people able reliably and effectively to control it; and vice-versa, the lower the class of the system the higher must be the class of operators working on it. For technical systems of a low class, for example, class 3, one would have to choose specialists no lower than class 5, weeding out about 60% of the candidates who wanted to master the given occupation, in this case (Figure 3). At the same time, the high-class technical systems will make such low demands on the specialists that control of such systems could be entrusted any healthy person. /305

In other words, there is a determinable relationship between the class of the operator and the class of the system he controls. This relationship can be expressed by the following formula of the reliability of the "man-automaton" system: $W_{op}+W_s>8$, i.e., the sum of classes of the operator and the technical system should be greater than the maximum point of the employed system of estimates. With the observance of this condition, the operator will reliably, effectively and stably maintain control over the system-technical complex, under the most varied conditions and regimes of work.

In citing the results of the above, one can draw the following conclusions.

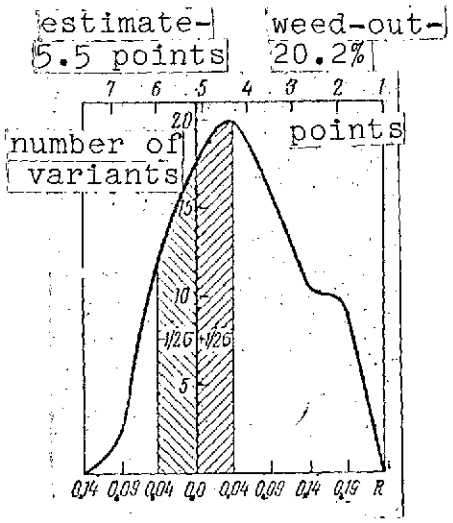


Figure 2. Estimating the class of a reconstructed system according to the level of reliability of sensory-motor control functions carried out by the operator.

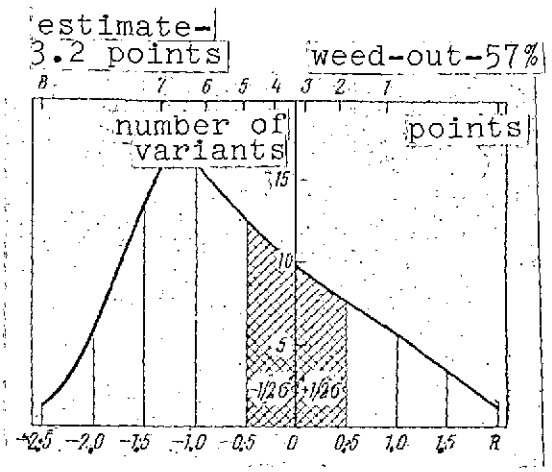


Figure 3. Determining the class of a system of indices according to the level of effectiveness of the operator's accomplishment of intellectual operations.

The all-regime systems-structural approach to studying psychologically the operator makes it possible to develop a unitary system of relative estimates of the qualification of the operator and the class of the technical system he serves; this will create new capacities for solving problems of optimizing the conditions of operator work in the system-technical complex. /306

The method of contructing non-dimensional scales for estimates examined by us predicates conducting tests on the actual technical system or its simulator, with the participation of an adequately large number of operators to obtain reliable statistical material. These tests are carried out for each of the structural functions in the optimum and extreme working regimes.

Comparative analysis of the indices of effectiveness of carrying out these functions in the extreme and optimum working regimes will make it possible to find the value of the index of quality of accomplishment of the given function under the extreme working conditions for each subject. Ranking according to this index and finding the boundary of octaves make it possible to compile the eight-point

system of estimates of the quality of accomplishing each of the operator functions. The general estimate of operator class can be carried out by means of finding the weighted mean point of estimates given for the accomplishment of specific functions.

Having contructed the distribution curves of the variants and having coordinated them with the uniform or non-uniform nomograms of the estimates, we can determine the class of a given technical system with respect to each of the structural functions. The comprehensive class of the technical system is calculated according to the formula of the weighted mean arithmetical estimate in points awarded the given system with respect to each of the basic elements of operator activity. The weight of the corresponding functions in the formulas of operator class and system class should be chosen identically.

Having determined the class of the system with respect to the average capacities of the operator controlling it, we can simultaneously predict the probably norm of weed-out and determine the lower boundary of operator pass point such that the basic condition of reliable and effective work of the operator in the given system-technical complex is observed. Engineering-psychological expertise pertaining to the quality of technical systems has been shown necessary by the following facts. Thus, for example, the cabin of the modern airliner has about 500 different indicators, dials, buttons, and control levers which the pilot must deal with.

In the extreme regime, the pilot is unable to observe and give /307
his attention to the readings of multiple indicators of the instrument panel. In the best case, he will escape the difficult situation based on the readings of 1 or 2 instruments. Serious difficulties must also be overcome by the pilot in making decisions.

One of the clearest consequences of ignoring the human capacities in constructing new equipment can be the tragic fate of the "Starfighter" fighter-bombers built by the American firm "Lockheed" for the FRG Bundeswehr. At the order of the customer, the firm

equipped the aircraft with a large number of electronic apparatus designed for making nuclear strikes. As a result, the atomic bomber became unreliable and hard to control. It is enough to say that over several years, in the FRG, 162 of the "Starfighters" crashed, comprising 23% of the total number of these aricraft purchased in the USA. 68 pilots died in these crashes.

All of the above indicates the need to further develop the theoretical principles and methods of complex engineering-psychological expertise pertinent to the quality of the system-technical complexes. Practical use of the data of such expertise will provide new prospectives for accelerating the tempo of scientific-technical progress and increasing the level of sophistication and effectiveness of our general industry, whose main activity has been and will remain man, in whose name and for whose good a new, communist society is being built.

REFERENCE

1. "Pravda", December 3, 1969.

Translated for National Aeronautics and Space Administration under contract No. NSw 2483, by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108.